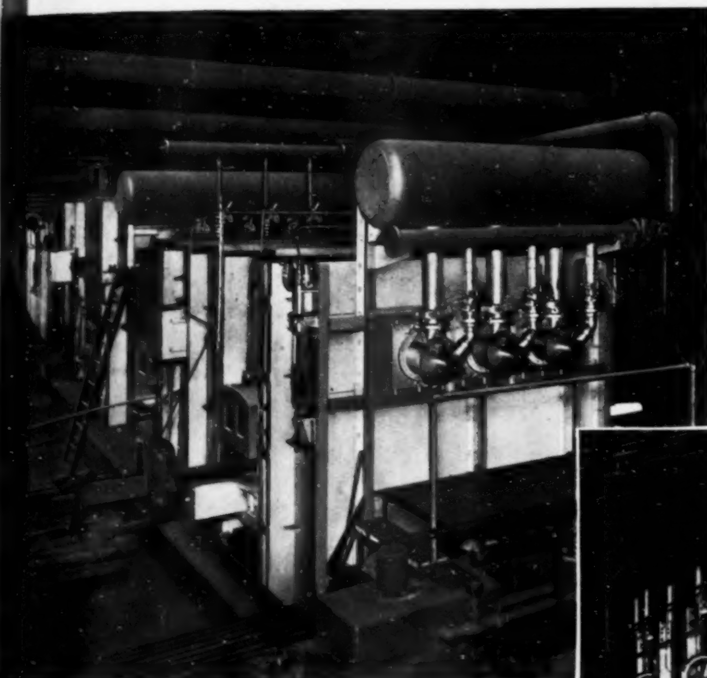
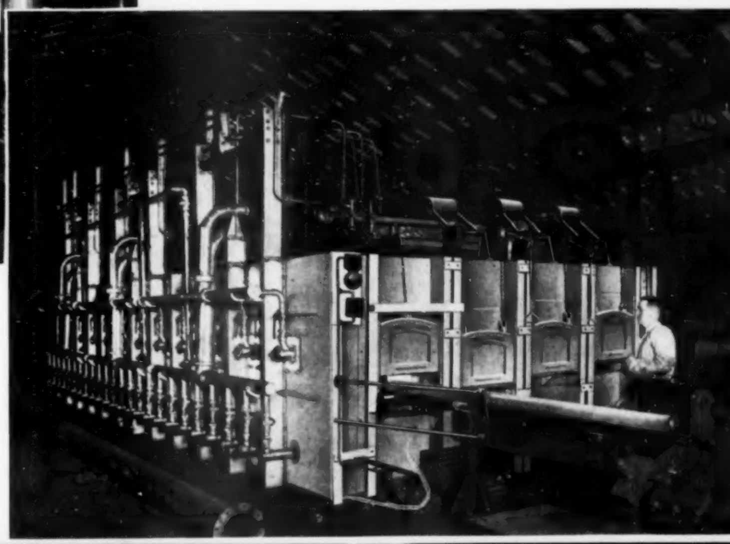
METALLURGIA
THE BRITISH JOURNAL OF METALS

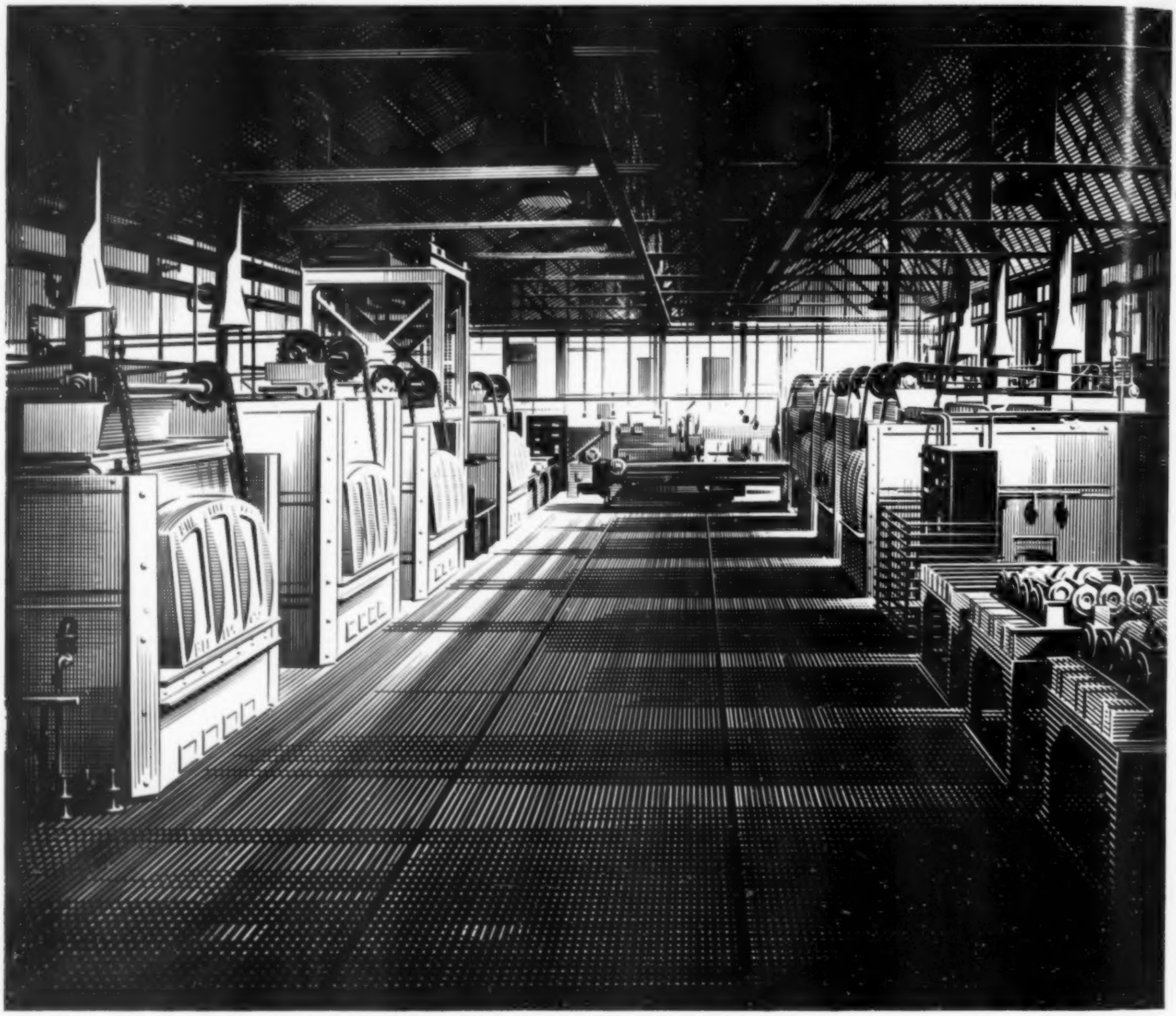
Vol. 56 No. 334 AUGUST, 1957 Monthly: TWO SHILLINGS



FURNACES FOR THE STEEL TUBE INDUSTRY



The illustrations show furnaces supplied to the new Tube Mill at Babcock & Wilcox Ltd., at Dumbarton. They include a gas fired Billet Heating Furnace, 6' x 70' (upper illustration). A Roll Down Tube Reheating Furnace, 35' x 10' 9" (centre illustration). A continuous Roller Hearth Furnace, ... x 90' (lower illustration)



METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR AUGUST, 1957 Vol. 56 No. 334

PUBLISHED MONTHLY BY

The Kennedy Press, Ltd., 31, King Street West, Manchester, 3.
Telephone: BLAckfriars 2084

London Office:

50, Temple Chambers, Temple Avenue, E.C.4.
FLEet Street 8914

CONTRIBUTIONS

Readers are invited to submit articles for publication in the editorial pages: photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

SUBSCRIPTIONS

Subscription Rates throughout the World—24/– per annum, Post free.

ADVERTISING

Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

The articles in this Journal are indexed in THE INDUSTRIAL ARTS INDEX

METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE "METALLURGICAL ENGINEER"

AUGUST, 1957 Vol. LVI. No. 334

Que Sera, Sera

POPULAR songs of the present time have their day and quickly cease to be, but the sentiments expressed in them are more lasting. About a year ago there was one with the title of "Que sera, sera"—translated as "Whatever will be, will be"—which may be taken to advocate contentment or complacency—two very different things. Contentment comes of a positive attitude towards circumstances, a willingness to make the best of them; complacency on the other hand represents a negative, defeatist attitude, a policy of drift.

At present there seems to be too little contentment and too much complacency. The Chancellor of the Exchequer's recent statement that no community could go on paying itself 7% more for no extra output without giving an extra twist to the inflationary spiral, whilst it was little more than a restatement of the position, at least showed an awareness that all is not well, but his subsequent self-satisfied appearance on television savoured altogether too much of complacency. Again, the Government has adopted an attitude of "do as I say, not as I do" on the matter of rising prices. Immediately an increase in wages is conceded to postal workers, up go the prices of most of the services provided by the G.P.O.—and some of them very steeply. Obviously one doesn't want the Post Office to be run at a loss, but there is a feeling that the Government set a particularly bad example to industry as a whole by giving the impression that rising wages inevitably mean an increase in prices. The Post Office must surely be an organisation which is unique in this or any other country if there is no scope for improvement in efficiency. There are, too, services which the G.P.O. performs for which the charges could reasonably be increased, such as the express letter service and evening collections from pillar boxes. These examples probably concern only a minute fraction of the postal traffic, but every little helps.

One of the worst features of rising costs, as far as inflation is concerned, is that they provide an opportunity for increasing prices. If the prices rose by no more than the increased cost it would be bad enough, but there is more than a suspicion that an increase of 5% in one of the factors making up the cost of an article is regarded as justification for increasing the cost of the article by 5%, even when the other factors are unchanged. In some instances, of course, the rise in price is taking into account cost increases which have previously been absorbed, with consequent reduced profits, but there is no room for complacency in this matter. The price of coal is particularly important in this respect, as it enters into the cost of so many other things, particularly transport and steel, any changes in the price of which have widespread repercussions. Although it may be economic heresy, one wonders sometimes whether it would not be preferable to maintain a steady price for coal by means of subsidies, if, by so doing, all round price stability could be more nearly achieved. Quite apart from the new wage claims that are initiated by higher prices, they make increasingly difficult the lot of those on fixed incomes who have no strike weapon with which to bargain.

In a recent newpaper article on the cost of strikes, it was pointed out that fears concerning their economic effect may be exaggerated, and that in the matter of lost time the 2 million working days lost in 1956 as a result of industrial disputes is but a small figure compared with the loss of 280 million days of "certified incapacity" in 1953–54, the last year for which the Ministry of Pensions and National Insurance records are readily available. The article concedes that the effects of industrial disputes upon the general public as well as the combatants may often be considerable in human and political terms, but suggests that in a democratic and dynamic economy wage adjustments and the bargaining that goes with them are inevitable, and that a policy directed at achieving such adjustments at the least long-term cost, and with the least loss of stability, cannot afford to treat strikes on the assumption that they mean economic disaster the moment they happen. Here again, however, there is no room for complacency, and recent strikes have shown tendencies which are not altogether healthy. The idea of a strike in most people's minds is to hold the employer to ransom by withholding that which is necessary for him to carry on his business, namely labour. Recently there seems to have been a tendency to hold the public, among them fellow trade unionists, to ransom, and to do so in a violent and offensive way.

In the recent debate in the House of Commons on economic policy the Chancellor is quoted as saying "Wages and profit increases must be related to production. This means adopting, on occasion, the old fashioned policy of saying, No. If saying No means some measure of disagreement—so be it. It is better to disagree than drift." The impact of the statement was seriously weakened by the fact that, even whilst Mr. Thorneycroft was speaking, the Industrial Disputes Tribunal was awarding an 11s.-a-week pay rise to the striking provincial busmen. In any case, however, it is still rather a negative attitude. As Mr. Aidan Crawley pointed out recently, what the Government should aim at is a series of joint meetings between management and unions in each industry to discuss not wage restraints but an increase in real earnings. On the side of management this involves an immense personal effort to get the new methods understood and accepted by the unions: on the union side it demands a relaxation of demarcation and other restrictions in return for easier and better organised work and higher earnings. The question of redundancy would no doubt be raised, but experience has shown that more problems in this category have arisen as a result of spasmodic operation of the credit squeeze than from planned reorganisation. Warnings and exhortations have been singularly unproductive; surely some more positive method is worth a trial.

Personal News

A NEW appointment—that of Technical Engineering Adviser (Retaining Ring Division)—is announced by Geo. Salter & Co., Ltd., of West Bromwich. The post will be filled by MR. M. M. POLSON, whose duties will take him throughout the country advising firms on the possibilities of cost reduction by using retaining rings instead of traditional methods of fastening.

SIR GEORGE BRIGGS has been appointed a Director of General Refractories, Ltd., Sheffield. Sir George, who is on the Boards of Brush Group, Ltd., Payne Products International, Ltd., Thomas Tilling, Ltd., and the Royal Ordnance Factories, is also a council member of the British Institute of Management.

FOLLOWING a decision by The Steel Company of Wales to reorganise their research on a divisional basis MR. A. J. K. HONEYMAN, has been appointed Superintendent of Research for the Steel Division. He will continue to exercise supervision over the Steel Division's Chemical and Metallurgical Department through the Chief Metallurgist. DR. C. S. BALL, has been appointed Chief Metallurgist, Steel Division, in sucession to Mr, Honeyman. He was appointed Assistant Chief Metallurgist in 1954, prior to which he was a lecturer at Birmingham University.

HIGH DUTY ALLOYS, LTD., announce the appointment of MR. W. H. BOWMAN, to the Board of Directors. For many years, Mr. Bowman has been a well-known figure in the non-ferrous metal industry. Prior to his new appointment, he was a Director of T. I. Aluminium, Ltd., and was responsible for the construction of their rolling Mill in South Wales. He was also a Director of the Aluminium Wire & Cable Co., Ltd.

AT the Annual General Meeting of the Norton Grinding Wheel Co., Ltd., the appointment was announced of MR. A. W. LEE as Managing Director. He will succeed MR. J. C. EWER who, as announced recently, is leaving to take up a new appointment with Norton Company, U.S.A.

MR. A. MAXWELL LEWIS, of the Metal Finishing Division of the Pyrene Co., Ltd., has been elected to the National Joint Council of the Metal Finishing and Allied Industries Apprenticeship Scheme, as representative of the Society of Motor Manufacturers and Traders.

MR. G. E. BROOKE, who has been on the engineering design staff of John Miles & Partners (London), Ltd., for 18 years, has been appointed to the Board of Directors.

MR. R. E. POWELL, Senior Vice-President of Aluminium, Ltd., and recently retired President of the Aluminium Co. of Canada, Ltd., has been appointed Chancellor of McGill University.

THE Effingham Steel Works, Ltd., Sheffield, announce that MR. G. BARBER has been appointed a Director of the Company to fill a casual vacancy.

MR. H. CAPPER has resigned his position with the Admiralty, Bath, to take up an appointment as Metallurgist with the British and Commonwealth Shipping Co., Ltd., 2, St. Mary Axe, London, E.C.3.

EDGAR ALLEN & CO., LTD., announce the appointment as Senior Representative in South and West Yorkshire North Lincolnshire, etc., of MR. J. T. WELLS.

MR. N. A. HART, of Baldwin Instrument Co., Ltd., has assumed responsibility for publicity for all members of the Harper Group of companies which includes, besides Baldwins, Harper Aircraft Co., Ltd., Stanley Engineering Co., Ltd., H.M.C. Wheels, Ltd., and Electrical Screws, Ltd.

MR. R. J. DIXON and MR. S. W. PERKINS, Directors of Wickman, Ltd., have been appointed to the Board of Arthur Scrivener, Ltd., Tyburn Road, Birmingham, 24.

MR. J. N. TAYLOR has been elected Chairman and Director of Modern Furnaces & Stoves, Ltd., in succession to the late MR. A. E. GRIFFITHS. MR. J. L. GOODWILL and MR. T. C. SHARPE remain as Joint Managing Directors

SIR CHARLES LILLICRAP, K.C.B., M.B.E., and MR. J. STRONG have been re-elected for a second year as President and Vice-President, respectively, of the Institute of Welding.

MR. M. SEAMAN, has, from July 1st, moved from the Board of British Oxygen Engineering, Ltd., to the Board of British Oxygen Gases, Ltd., where he will be Director responsible for equipment manufacture.

MR. F. BUCKLAND has been appointed Secretary and Office Manager of United Coke and Chemicals Co., Ltd., and of the Ore Mining Branch of the United Steel Cos., Ltd. He succeeds MR. S. BACON, who retired at the end of June after 49 years' service.

MR. D. CRAIG has been appointed Melting Shops Superintendent of Steel, Peech and Tozer, a branch of the United Steel Cos., Ltd., in succession to MR. J. T. BROOKES, who has retired after 50 years' service.

MR. N. L. G. LINGWOOD, Distribution Director of British Oxygen Gases, Ltd., has been re-elected President of the British Acetylene Association.

THE Council of the British Cast Iron Research Association has appointed MR. H. MORROGH to be Deputy Director and DR. H. T. ANGUS to be Assistant Director to DR. J. G. PEARCE, C.B.E. (Director). Both Mr. Morrogh and Dr. Angus will continue in their functions as Research Manager and Development Manager, respectively.

MR. J. W. MILLS, O.B.E., for over twelve years a Director of Armstrong Whitworth (Metal Industries) Ltd., and Jarrow Metal Industries, Ltd., has decided to relinquish his seat on the Board, in order to reduce his business commitments.

Obituary

WE regret to record the death, at the age of 84, of LORD RIVERDALE, until last May the Chairman of Arthur Balfour & Co., Ltd., Sheffield. Apart from his lifelong connection with Balfours, Lord Riverdale played a large part in the formation of High Speed Steel Alloys, Ltd., in 1914, and served on the boards of the Telegraph Construction & Maintenance Co., Ltd., C. Meadows & Co., Ltd., and Submarine Cables, Ltd. In 1911, at the age of 38, Mr. Arthur Balfour, as he was then, was elected Master Cutler, and at the time of his death was the oldest surviving Master Cutler.

Lord Riverdale had many interests, both inside and outside industry, and he will long be remembered for his work in connection with the Boy Scout movement, the Air Training Corps, and other youth organisations, and as Chairman of the Appeals Committee of the Royal Air Force Benevolent Fund.

Electrical Equipment for a Cold Cut-up Line

Heavy Gauge Installation at S.C.O.W.

A general view of the 74 in. × $\frac{3}{8}$ in. cut-up line from the entry side.

A LARGE proportion of the industrial demand for steel plate in gauges up to $\frac{3}{8}$ in. is now met by material produced from high-speed continuous rolling mills. Until recently, plates over $\frac{3}{16}$ in. thick were obtained either from the mill as fly-sheared lengths, or as lengths of plate processed through the orthodox cooling bank and end shears. Either method restricted the potential capacity of a fast-moving continuous strip mill. The Steel Company of Wales, Ltd., has recently extended the use of coilers to cover all gauges up to and including $\frac{3}{8}$ in., and it has, therefore, been necessary to design and install a cut-up line capable of decoiling, flattening and shearing these thicker gauges.

The 74 in. by $\frac{3}{8}$ in. cut-up line now in commission at the Abbey Works of the Steel Company of Wales is the first of its kind to be installed in this country, and is designed to cut strip from 15-ton coils into lengths ranging from 4 ft. to 36 ft. and to flatten and pile the cut lengths. It can be operated under automatic or manual control, the maximum speed of operation when cutting $\frac{3}{8}$ in. steel being 150 ft./min., rising to 250ft./min. for $\frac{3}{16}$ in. steel. The General Electric Co., Ltd., was the main contractor for the whole of the electrical plant and control gear for this installation, and was responsible for the design of the control scheme. Basically this is a Ward Leonard system operating in conjunction with control exciters which enable high cutting speeds to be attained with accuracy and complete stability. The consulting engineers for the contract were McLellan and Partners.

An interesting feature of the installation is that the control desks incorporate a new type of master control switch designed in conjunction with the consultants. These switches enable the operators to have large numbers of controls within easy reach whilst seated at their desks.

At the entry section of the line, coils of strip are loaded by means of a coil carriage on to a pay-off reel, which is coupled to a 40kW. drag generator used to maintain constant tension in the strip during its passage through the section. On leaving the reel, the strip enters a processor which flattens the material prior to shearing, and then passes to the entry tables and through a pair of pinch rolls to the Head Wrightson electrically driven up-cut shear. After shearing, the plates pass to the delivery section of the line, which comprises the shear gauge tables, a roller-leveller, a further pair of pinch rolls, an inspection table with automatic rejection, and a run-out table from which the finished plates are piled ready for removal.

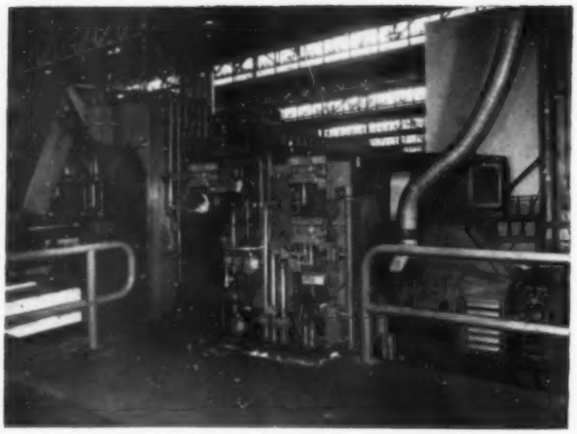
Automatic Operation

The control scheme provides for automatic operation, in addition to the usual facilities for manual control, threading and inching. When automatic operation is used, the whole of the entry section of the line stops each time a plate is sheared; the shear gauge table starts and stops with the entry section, but the rest of the delivery section normally runs continuously. Under these arduous conditions, where the whole of the entry-section drives have to be accelerated and decelerated each time a cut is made, the rapid response of the control exciter system is of considerable value in enabling high output to be maintained from the cut-up line.

The D.C. power supplies for the various drives are obtained from a motor-generator set comprising a 700 h.p., 3·3kV. induction motor direct-coupled to two 0/300 kW., 0/400/500 V. D.C. generators. This M.G. set also includes a 3kW. booster which is connected in series with the drag generator, and a 15kW. exciter with a constant voltage output which provides the excitation for the motors driving the cut-up line.

The 4-machine exciter set for the control of the cut-up line is driven by a 10 h.p., 415 V. squirrel cage motor, and includes a 5-field exciter associated with the entry side generator, a similar exciter for the delivery side generator and a 4-field exciter for the drag generator. This exciter set is installed, together with the main D.C. switchboard, in the basement of a two-storey substation. The upper storey of the substation, which is at mill floor level, provides accommodation for the D.C. control gear.

The drag generator and the eight D.C. motors driving the various sections of the line are forced-ventilated machines with separately excited fields. Cooling air is fed to each machine from a common air supply, either by



The drives for the entry section, showing the 40kW. drag generator (right foreground), with the 250 h.p. motor for the processor mounted above the generator.

trunking or by ducts in the foundation blocks, and is exhausted through louvred apertures. The processor motor is rated at 0/250 h.p. at 1,000 r.p.m. max., and that for the roller leveller at 0/225 h.p. at 1,150 r.p.m. max., while the six machines driving the tables and pinch rolls total approximately 180 h.p.

The main D.C. switchboard for the cut-up line is of sheet steel construction, and is built in two portions mounted back-to-back and separated by a central gangway, which enables ready access to be obtained to all back-of-board components for inspection and maintenance.

Control Desk

The operation of the complete line is controlled from console-type desks located at the entry section, the up-cut shear and the finishing section. The control desk for the shear is constructed of stainless steel, and the centre section embodies a total of 34 control switches which are arranged, together with the necessary indicating instruments, in two manuals. As the overall width of the new-type switch is only $1\frac{1}{8}$ in., the whole of the controls for the section are located within easy reach of the operator's hands. Further advantages of these switches are that the contact arrangement can readily be adapted to suit all normal control requirements, and that the complete switch mechanism can be quickly unplugged from its housing for inspection and maintenance. The cabinets at the ends of the desk provide accommodation for the indicator lamps, emergency stop push button, and the various regulators and potentiometers associated with the control scheme. The shear control desk forms the principal control centre for the complete line; the desks for the entry and finishing sections are similar to the shear desk in design, though the number of circuits controlled from these is smaller.

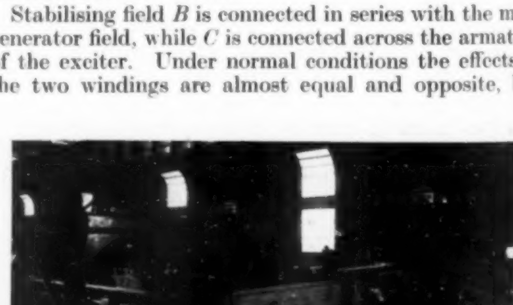
The entry and delivery sections of the line are separately controlled, and each is equipped with its own generator and associated control exciter. The exciters are basically voltage-controlled, though a current-limiting feature is incorporated to prevent excessive acceleration and retardation of the line. The two main generators are identical, but the maximum voltage of the entry section generator is limited to 400V., while the output of the delivery section generator at full speed is 500 V. This voltage difference enables the delivery section to run faster than the entry section, and so clear the cut lengths from the shear. Regulators for controlling both the crawl and running speeds of the line are provided on each desk.

Features of Control System

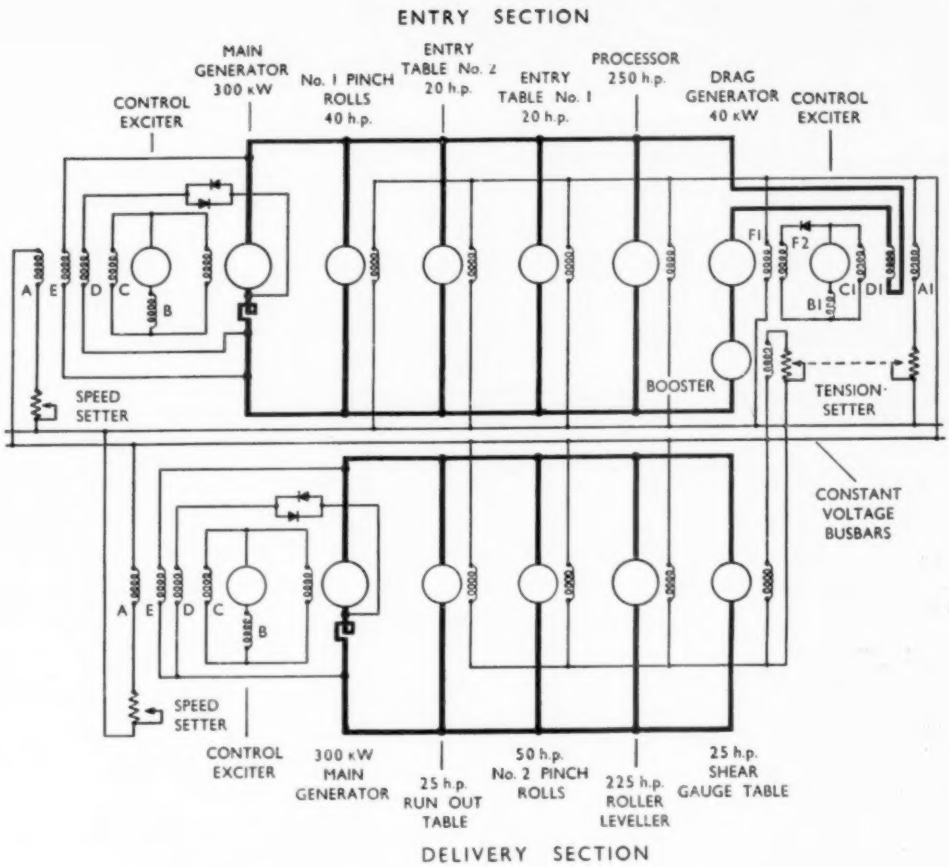
As shown in the schematic diagram, the control exciters for the main generators are each equipped with five field windings, of which *A* and *B* are positive fields which tend to increase the voltage output of the exciter, and *C*, *D* and *E* are negative fields which produce the reverse effect. *A* is the voltage setting field which enables the speed of the section to be controlled from the regulator on the control desk. *B* and *C* are stabilising windings, *D* is the current limit field which is connected in series with a metal rectifier across the compoles of the main generator, and *E* is the voltage resetting field which is connected across the main generator.

The control system functions in the following manner. A voltage proportional to the desired speed of the section is fed to field *A*. The voltage output of the control exciter, and hence of the main generator, builds up until the voltage across field *E* nearly equals that across field *A*, the slight difference being sufficient to keep the main generator excited at the desired voltage. If the voltage fed to field *A* is reduced, field *E* will predominate and the voltage output of the exciter will be reduced until fields *E* and *A* are again almost in balance. If field *A* is reduced to zero, regenerative braking will be applied to stop the section. During acceleration or retardation, any increase in current above the set value of twice full load will cause the current-limit rectifiers associated with field *D* to become conductive. The resultant current in *D* tends to reduce the main generator voltage during acceleration and to increase the voltage during retardation, thus limiting the load current to the set value.

Stabilising field *B* is connected in series with the main generator field, while *C* is connected across the armature of the exciter. Under normal conditions the effects of the two windings are almost equal and opposite, but



The control desk for the up-cut shear.



Simplified schematic diagram of the entry and delivery sections.

during rapid changes B will lag behind C because of the inductance of the main generator field. Field C, acting as a source of negative feedback, will then cause the output voltage of the exciter to fall, thus preventing hunting. In practice, B is made slightly more powerful than C, and acts as a self-sustaining series field for the exciter, so that a small difference between the setting and resetting fields will produce full output from the exciter, thus increasing the accuracy of the system.

The drag generator is used to maintain a constant tension in the strip during its passage through the entry section. The generator has two field windings, $F1$ and $F2$, of which $F1$ is excited from the constant voltage busbars and is set to give an empty-reel speed slightly slower than the entry section. The second field, $F2$, is energised from the control exciter via a blocking rectifier which ensures that field $F2$ can only assist field $F1$. In series with the drag generator is a booster which is excited from the constant voltage bars via a regulator ganged to the tension setter. This regulator is graded so that the booster produces a voltage proportional to the IR drop in the circuit. The booster is necessary to ensure effective control at very slow speeds, and is also used for inching the drag generator and for providing stalled tension when the line is stopped.

The control exciter for the drag generator has four field windings $A1$, $B1$, $C1$ and $D1$, of which $A1$ and $B1$ are positive fields which tend to increase the voltage output, and $C1$ and $D1$ are negative fields which reduce the output. Field $A1$ is the tension setting field which is excited from the constant voltage bars in proportion to the desired tension, and causes full field to be applied to the drag generator. As the coil of strip on the pay-off reel is unwound, the speed of the drag generator will increase in proportion with the decreasing coil diameter, and, in consequence, the back e.m.f. will rise, causing the feedback current to increase. The current resetting field $D1$, which is in series with the main drag generator circuit, will then oppose field $A1$ and so reduce the drag generator field and consequently the back e.m.f. This process continues all the time strip is being payed off the reel, field $D1$ being slightly greater than field $A1$ to maintain the set tension. To prevent a loop from being thrown during retardation, the tension is increased to provide a component of current proportional to the braking torque.

Fields $B1$ and $C1$ of the control exciter are stabilising fields, $B1$ being connected in series with the controlled field and $C1$ across the armature of the control exciter. These windings act in similar manner to fields B and C of the exciters for the main generators, the functions of which have already been described.

Protective Devices

When the line is operating under manual control, the various sections are under the individual control of operators seated at the three control desks, and interlocks are provided to ensure that there can be no change to automatic control while the line is running. Dual controls are provided for inching the mandrel and processor, and a changeover relay on the master control desk at the shear enables the control to be transferred from the shear desk to the entry desk. When automatic control is selected, the starting and stopping sequences are initiated by limit switches actuated either by a cut length or by the leading edge of the advancing strip.

A comprehensive system of interlocks, relays and protective devices has been installed to prevent the line from being started until the shear motor and all A.C. auxiliary drives such as oil pumps, hydraulic pumps, and fans are in operation, and to prevent damage should the various controls be operated in an incorrect sequence. In addition, overload and field failure protection has been provided for all the driving motors, while the generators are equipped with both time-delay and instant-trip overload and overvoltage protection.

Acknowledgment

Acknowledgment is due to the Steel Company of Wales, Ltd., for permission to photograph the installation and to publish this description of it.

New and Revised British Standards

Solid Drawn Copper Alloy Tubes for Heat Exchange Equipment in the Petroleum Industry

(B.S. 1464 : 1957). Price 4s.

This revised edition of B.S. 1464 specifies requirements for the following alloys (the 1948 edition specified only the first two) :—

	Symbol
Aluminium Brass	CZ 110
Admiralty Brass	CZ 111
7% Aluminium Bronze (copper aluminium)	CA 102
70/30 Brass	CZ 105
70/30 Copper Nickel	CN 107

The designating symbols are those to be used in the forthcoming British Standard " Schedule of Copper and Copper Alloy Tubes." The two sections of the publication (" General Clauses " and " Specific Clauses " respectively) are supplemented by an Appendix which contains eight half-tone photographs illustrative of grain size and reproduced by courtesy of the American Society for Testing Materials.

Corrugated Aluminium Sheets for General Purposes

(B.S. 2855 : 1957). Price 3s.

Corrugated aluminium sheets are increasingly used in building as roofing sheets and for other purposes. The Aluminium Development Association therefore asked B.S.I. to publish a standard for such sheets, and this has now been issued as B.S. 2855. The standard sets out specifications for corrugated aluminium sheets in two widths of 8/3 in. and 10/3 in. corrugations respectively. A further standard for troughed aluminium sheets is now in course of preparation. B.S. 2855 does not include details as to the use of these sheets. Recommendations on their use for roofing will be the subject of a Code of Practice now being prepared.

Methods of Testing Refractory Materials

(B.S. 1902 : 1957)

Addendum No. 1 : 1957

Methods for the Direct Determination of Alumina

Price 3s. 6d.

It has long been recognised that the estimation of the alumina content by difference is a major defect in the " classical " procedure of silicate analysis, and the development of a direct method of determination was the first task assigned to the Chemical Analysis Sub-Committee of the British Ceramic Research Association, when it was formed in 1946. Details of the recommended methods were issued by the British Ceramic Research Association to its members, and these methods have been in use in industrial and research laboratories for several years. With minor revisions, these methods form the basis of Addendum No. 1 to B.S. 1902, and should in general be used in preference to the " difference " method described in that standard. Part 1 specifies a method for the direct determination of alumina in silica rocks, sands and silica refractories containing 0·1–10% alumina ; and Part 2 specifies a method for the direct determination of alumina in alumino-silicate refractories and raw materials containing 10–65% alumina.

Copies of these new standards can be obtained from the British Standards Institution, 2, Park Street, London, W.1.

Alcan's New Power Project

Aluminium Company of Canada, Ltd. (Alcan), is making steady progress with its vast new hydro-electric power project at Chute-des-Passes on the Upper Peribonka River in Quebec. The project involves blasting a 6 mile long tunnel to connect the reservoir with an underground powerhouse now being excavated. The powerhouse cavern will house five 200,000 h.p. turbo-generators utilising a gross head of 635 ft. when the reservoir is full. At the powerhouse end, the 35 ft. dia. tunnel will divide into five penstocks. Three thousand men are now at work drilling the tunnel, access to which is provided by three adits. The waters are discharged through a second 1½ mile long tunnel into the Peribonka River flowing south for use again in the Saguenay area power stations.

When completed the new project will add a million horsepower capacity to Alcan's power network for smelting aluminium, at a cost of about $150,000,000. First power should flow by summer 1959, while the entire project will be completed by mid-1960. A new transmission line will be built to carry the power 100 miles south from the new powerhouse to Isle Maligne, where it will be distributed to Alcan's smelters in the area. The Chute-des-Passes Development is part of a previously announced expansion programme in Quebec, which includes the construction of facilities to produce an extra 120,000 tons of aluminium in the Saguenay area.

The Physical Properties of Electrodeposited Metals

By T. E. Such, B.Sc.*

The wide variations in physical properties—i.e. tensile strength, ductility, hardness and internal stress—that can be obtained in electrodeposited metals are discussed. A description is given of the way in which these metals and articles plated with them are affected by changes in these properties, and methods for their determination are considered.

THE physical properties of electrodeposits are obviously of importance in engineering applications, but they can also be vital if the plate is being used for decoration or protection against corrosion. The most critical physical properties of plated metals are tensile strength, ductility, hardness and internal stress. The strength of a metal is its ability to resist deformation, while ductility is the ability to deform without fracture. Hardness is not such a fundamental property of metals and the value obtained depends on the method of measurement, but it can be related empirically to the more fundamental properties such as tensile strength and elongation. It is, therefore, often employed for production control purposes, as it is usually a simple matter to determine the hardness of massive metals. Internal stress is thought to be caused by a volume change occurring in the plated metal soon after deposition. If the deposit is firmly adherent to a rigid base, it cannot alter its shape and so remains in a state of stress, which can be either tensile or compressive in nature. When the stress is tensile, this is due to the plate attempting to shorten itself and to have a length shorter than the article on which it is deposited, and conversely with compressive stress.

It is noteworthy that very wide changes in the properties of electrodeposits of the same metal can be induced by variations in the conditions of deposition. Even the softest of these electrodeposits is often harder than the same metal which has been fully annealed. Many deposits are harder than can be obtained even by work hardening the same metal, as can be seen from Table I, which is based on that given by Macnaughtan and Hothersall,[1] with some slight modifications taken from later work. The softest deposits are usually obtained from very pure plating solutions, while the hardest ones are generally given by solutions which contain organic addition agents. Chromium is an exception to this general rule.

The other physical properties of electrodeposited metals exhibit just as great variation, as illustrated by the examples given in Table II.[2] These values are extreme limits, but the width of each range shows what widely differing properties are available from electrodeposits, properties which may be unobtainable from the same metal in the wrought condition. By varying the composition of the plating solution and the conditions under which it is operated, it is therefore possible to obtain metals which are nominally the same, but which are very different in their physical characteristics. This will be discussed later, but the importance of being able to obtain deposits with any desired properties will now be considered.

TABLE 1—HARDNESS OF ELECTRODEPOSITED AND WROUGHT METALS

Metal	Brinell Hardness Number		
	Electro-deposits	Fully Annealed	Work Hardened
Cadmium	12–60	20	34
Chromium	400–1100	70	—
Copper	35–190	40	102
Iron	130–380	69	148
Nickel	130–600	70	300
Palladium	190–435	49	109
Platinum	606–642	47	97
Rhodium	600–800	101	—
Silver	60–130	25	68
Tin	8–9	4–5	—
Zinc	40–120	33–40	52

TABLE II—PHYSICAL PROPERTIES OF SOME ELECTRODEPOSITED METALS.

Metal	Tensile Strength Range (lb./sq. in.)	Ductility Range (% elongation)	Internal Stress Range (lb./sq. in.)
			Compressive Tensile
Chromium	15,000–80,000	0	17,000–150,000
Copper	15,000–60,000	2–40	5,000–15,000
Nickel	50,000–225,000	0–30	10,000–60,000
Zinc	4,000–35,000	0–50	2,000– 2,000

IMPORTANCE OF PHYSICAL PROPERTIES

In Wear Resistance

The use of heavy nickel or hard chromium deposits on bearing and other surfaces where much wear is encountered is well known and needs no elaboration. Originally employed only to salvage worn or over-machined parts, thick deposits of chromium are now often used to lengthen the life of articles such as cylinder liners, tools and dies. The hardness and low coefficient of friction of chromium make it the ideal coating where resistance to abrasion is needed. If more than 0·010 in. of plate is needed for building-up any article, nickel is often preferred to chromium, although it is not so hard, as the cost is less. Nickel deposits from the Watts type solution have a hardness of about 200 V.P.N., but this can be increased to approximately 350 if ammonium salts are used as a buffer instead of boric acid.[3]

For engineering applications where resistance to wear is essential, the hardness of the deposit is the most important property, the ductility, in the majority of cases, being a secondary consideration. For some purposes, such as bearing liners, a soft metal with a low coefficient of friction is needed, and here alloy plating, such as with tin-lead, has proved a success.

In Fatigue Resistance

It has been shown by many workers that electrodeposits in a state of tensile stress reduce the fatigue

* Formerly of Wilmot Breeden, Ltd, Birmingham 25 : present address, Ionic Plating Co. Ltd. Birmingham, 18.

TABLE III—SHARPEST BEND WHICH BRIGHT NICKEL PLATED ARTICLES WILL STAND BEFORE THE DEPOSIT CRACKS.

Type of Solution	Condition of Solution	Radius of Curvature
Organic bright nickel with levelling action	Used	Almost infinity
As above	Fresh	2 in.
Organic bright nickel without levelling action.	Used	0·7 in.
As above	Fresh	0·2 in.

strength of the article on which they are plated. As nickel and chromium deposits normally have the highest internal tensile stresses, they are the worst offenders in this respect. In many applications the risk of fatigue failure is not present, and the reduction in fatigue strength after plating is of no significance. When fatigue failure is liable to occur and chromium or nickel plating must be used, it is still possible to avoid reducing the fatigue resistance of the component ; in fact, the fatigue strength can be improved. If the surface of the article in question is in compressive stress, this will bring about the desired increase in fatigue strength. For example, if nickel deposits are employed, they can be plated in a state of compressive stress by adding certain organic chemicals to the plating solution, providing the brittleness caused by this is of no consequence. Dull nickel plate is deposited from a Watts type bath in a state of tensile stress, but compressive stress can be induced in the surface of the nickel by shot-peening it.[4] If neither of these methods is applicable, the deleterious effect of the nickel can be reduced by the use of an undercoat of lead. The lead yields plastically and so prevents the transmission of stress to the underlying metal when fracture occurs in the nickel deposits.

Shot peening of chromium deposits will improve the fatigue strength of a chromium plated part. Chromium can be deposited in a state of compressive stress if a suitable solution and operating conditions are chosen, and so actually increase the fatigue limit of the plated article.[5, 6] It is often recommended that high tensile steels should be heated to 200° C. after chromium plating to relieve hydrogen embrittlement. Hammond and Williams[5] have recently demonstrated that this low temperature heat treatment decreases the fatigue strength of the component. If certain components are to be subjected to alternating stresses during their working life, they should not be heat treated after chromium plating or, alternatively, they should be heated to at least 440° C. (preferably 520° C.), if the resultant deterioration in the hardness of the chromium and the mechanical properties of the basis steel can be tolerated.

Zinc plating improves the fatigue limit of steel components, due to the compressive stress in the deposit. It is particularly beneficial when corrosive conditions are experienced simultaneously with alternating stresses, where corrosion-fatigue would rapidly cause unplated steel to fail. Where hardness of the surface is not essential, a zinc deposit should be used in preference to nickel or chromium on any steel article whose failure due to fatigue would have serious consequences.

In Forming and Drawing

The main criterion for an electrodeposit on an article that must be formed into a different shape is high ductility. There is usually no difficulty in fabricating tin-plate or electro-galvanised sheet and wire and it is possible to obtain dull nickel plated steel sheet for manufacturing articles where considerable deformation of the deposit is involved. However, when it is desired to bend—even if only slightly—a part which has been plated in an organic bright nickel solution, then the operation becomes much more critical. The nickel deposit is often so brittle that it can only be bent with a large radius of curvature, and to attain any success it is necessary to maintain the bright nickel solution in as pure a state as possible. Some bright nickel deposits can be formed or drawn, but those which have the greatest levelling powers are the most brittle and will withstand the least deformation. Particularly is this so after chromium plating, as the hydrogen evolved during this operation will have further embrittled the nickel, as will be discussed below.

For the majority of applications involving forming of plated articles, only a trial will show whether an electrodeposit will stand up to any particular operation. As a general guide, Table III shows the minimum radius of curvature which unchromed deposits from organic bright nickel baths will withstand without cracking.

Cobalt-nickel and organic semi-bright deposits will stand even sharper bends without fracturing. However, it must be remembered that deposits stressed by forming will be more liable to crack during service, and it is wise to make corrosion tests on the formed article and not just accept it as satisfactory if no cracks show immediately after the forming operation.

TABLE IV—THE REDUCTION OF STRESS IN COBALT-NICKEL DEPOSITS.

Additions to Cobalt-Nickel Solution	Stress in Deposit (lb./sq. in. tensile)
None	57,600
0·13 oz./gal. saccharin	13,400
0·19 oz./gal. saccharin	7,300

In Electroforming

An electroform must be free from internal stress if it is to fulfil its purpose of being an exact replica of the master pattern on which it was plated. Otherwise when taken from the master it will warp in order to relieve this stress. If the stress is high enough, the electroform will even curl away from the mould during the deposition process, as the adherence of the plate to the plastic or wax that is often used is of a low order. Copper deposition is frequently used for preparing electroforms, as the deposit possesses only low stress and so will not distort. Copper does not, however, possess the hardness and strength which is necessary if the electroform is to be used for printing type or as a die for moulding plastics. Here the hardness of nickel is essential : sometimes the greater hardness of the cobalt-nickel alloy deposit is needed.[7] Unfortunately nickel deposits are normally highly stressed in tension. This tensile stress can be reduced or even made compressive by adding certain organic chemicals to the nickel plating solution, and saccharin and sodium naphthalene trisulphonate have been used for this purpose. The effect of adding saccharin to a cobalt-nickel solution is shown in Table IV. Super-imposed A.C. on D.C. has also been shown to lower the stress in nickel deposits.[8] The hardness of nickel can be combined with the low stress of copper by first depositing the nickel to give a hard surface, and then backing this nickel by such a thick layer of copper that it will not be warped by any stress in the nickel. After removing the electroform from the master, the nickel can be chromium plated to provide an even harder surface if necessary.

In Corrosion Resistance

It has been pointed out before that the physical properties of the electrodeposit can influence the

corrosion resistance of the plated article.[9] Most of the work on this subject has been carried out on nickel and chromium deposits, for it is these metals that are most prone to failure by cracking. Bright nickel deposits are often deposited in a brittle state, and if this brittleness is combined with high internal tensile stress, cracking of the plate with exposure of the basis metal may occur immediately, or soon after plating, if the stress locally exceeds the tensile strength of the nickel. Even if this spontaneous cracking does not take place, service cracking may be caused during the life of the plated article, either due to deformation or to stress-corrosion, probably initiated by a surface scratch. Read[2] has also postulated that if the internal stress is not uniform, but varies from one spot in the deposit to another, which is probable, then corrosion is likely to occur owing to the establishment of anodic and cathodic areas on the coating.

It is important to emphasise the difference between internal stress and ductility. There is no relationship at all between these two properties. Dull nickel deposits from the Watts bath may be highly stressed in tension and yet have excellent ductility, while organic bright nickel deposits may have zero stress and still be very brittle.

The high internal stresses in chromium are responsible for the limiting thickness of 0·00002 in. allowed for chromium for decorative purposes. If thicknesses of chromium much greater than this are used the deposit will tend to crack.

In Polishing

Although there is no doubt that, generally speaking, the softer the metal the easier it is to polish to a high lustre, a low hardness is by no means the only criterion for good buffability. The semi-bright nickel deposits are easier to mop than their dull counterpart ; they are not so "draggy" and do not tend to cling to the buff. DuRose, Karash and Willson[10] give comparative values for buffing of three types of nickel deposits : the results they obtained are set out in Table V. A few attempts[11, 12] have been made to relate buffability with hardness or other properties of the electrodeposit, but it is difficult to define "easy polishing" and even more difficult to give it a numerical value, and no valid correlation has yet been demonstrated.

FACTORS INFLUENCING PHYSICAL PROPERTIES

Co-deposited Materials

The properties of tensile strength, ductility and hardness of an electrodeposited metal are only influenced by material which is co-deposited with the metal. It follows that only substances present in the plating solution which either are co-deposited themselves, or else influence the co-deposition of other material, can alter the properties of electrodeposits. It is, therefore, the composition of the plating solution, rather than the operating conditions, that plays the major part in determining the properties of a deposit. Provided the operating conditions—temperature, current density, agitation, etc.—are kept within limits normally accepted as satisfactory, then these conditions will have only a small effect on the physical properties.

The material included in a plated metal may be either metallic or non-metallic in nature. Traces of other metals have less effect than similar quantities of non-

TABLE V—RELATIVE EASE OF POLISHING OF NICKEL DEPOSITS.

Type of Nickel	Drag on* Mop	Lustre* after Equal Polishing	Relative* Decrease in Thickness	Knoop Hardness
Dull	2·3	16	500	179
High-chloride dull	1·3	47·5	300	215
Semi-bright	1	100	100	346

* These are comparative figures only.

metals, such as carbon, sulphur and oxygen. For example, Brenner[13] has postulated that the variations found in nickel deposits obtained under different conditions from the same basic type of dull nickel plating solution may be directly related to the oxygen content of the deposit. This oxygen is probably derived from the basic nickel salts present in the cathode film. It may be that traces of these non-metallic impurities exert more influence than small quantities of metals because their distribution in the deposit is different. Oxides, sulphur, carbon, etc., may segregate round grain boundaries, producing a fine-grain structured metal whose lattice will be distorted, giving rise to hardness and brittleness. Co-deposited metals will form alloys with the impurity, going into solid solution in the majority of cases. If only small amounts of the second metal are present ($<0{\cdot}1\%$) then the impure deposit will not differ significantly from the pure in most physical properties.

Hydrogen Embrittlement

It is not necessary for co-deposited matter to be solid—gaseous hydrogen will alter the hardness and ductility of electrodeposited metals of the iron group. The hydrogen evolved during the chromium plating of a nickel plated article will seriously embrittle the nickel : an illustration of this is provided by the following experiments.

The ductility of a dull nickel deposit was determined before and after chromium plating, by a method which the author has previously described.[9] The chromium was removed by anodic dissolution in caustic soda and the ductility of the nickel then determined both with and without a stress relieving heat treatment. The results shown in Table VI were obtained. (An organic bright nickel deposit was included for comparison.)

The chromium plate must have cracked as soon as the slightest elongation of the tensile test-piece took place, but these cracks do not appear to have had a notch effect on the nickel below. The chromium cracks are very fine and impossible to resolve at the ×6 magnification normally used for examination of the surface during this test. Where they have appeared as a haze, they have been ignored and stretching of the test-piece continued until the nickel itself has cracked. These results show that the majority of the embrittling

TABLE VI—HYDROGEN EMBRITTLEMENT OF NICKEL DEPOSITS.

Type of Deposit	Ductility in Arbitrary Units	
	Dull Nickel	Bright Nickel
(1) Nickel deposit before chromium plating	23	9
(2) Nickel deposit after chromium plating.	10	—
(3) Nickel deposit after chromium plating, but with chromium stripped off.	12	4
(4) Nickel deposit after chromium plating, but after heat treatment.	24	—
(5) Nickel deposit after chromium plating, followed by heat treatment and then chromium stripping	26	—
(6) Nickel deposit not chromium plated, but made cathodic in an alkaline solution for 5 minutes.	7	—

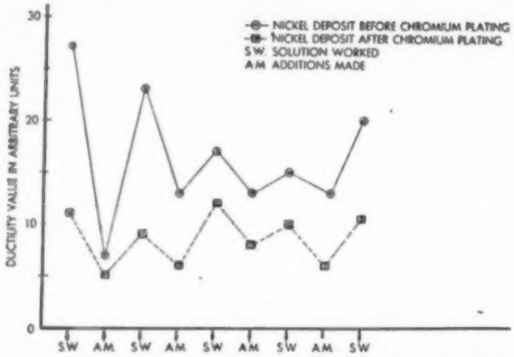


Fig. 1.—Variation in ductility of bright nickel deposits before and after chromium plating as the nickel solution is worked.

effect of chromium plating is due to the hydrogen evolved and occluded in the nickel, and not to the brittle surface layer deposited.

Many ductility determinations have been performed in the author's laboratory on nickel deposits before and after chromium plating. The values found for these coatings indicate that the ductility of a chromium plated nickel definitely depends on that of the nickel before chromium plating, i.e. increasing the ductility of the bare nickel will result in a more ductile nickel after chromium plating. However, changes in the ductility of nickel after chromium plating do not follow the same ratio as those for bare nickel; e.g. bare nickel plate with double the ductility of another will not have double the ductility after chromium plating—the factor will be less. Nevertheless, the trend is always present for the most ductile nickel to be also the most ductile after chromium plating. This is illustrated in Fig. 1, showing the variation in ductility obtained as a bright nickel solution is worked.

It should be noted that to remove all the hydrogen the stress-relieving heat treatment should be carried out at 200° C. Lower temperatures are not effective except over long periods. Although the hydrogen is claimed to diffuse slowly out of the nickel at room temperature, no increase in ductility was found even after seven weeks standing.

Internal Stress

While the internal stress of electrodeposits is also altered by changing the composition or operating conditions of the plating solution, it cannot be related to the other three physical properties. A number of theories have been put forward to explain the phenomenon of internal stress. Some investigators have attempted to explain it on the basis of the co-deposition and inclusion of hydrogen. Others have postulated that stress is caused by the co-deposition of basic material, as with nickel at high pH. However, stress is found in metals which are deposited in a very pure state at 100% cathode current efficiency, and so neither of these explanations holds good for all metals, although they may be factors in particular cases. Wilman[14] has recently put forward the hypothesis that the temperature on a growing cathode surface is much greater than that of the solution temperature, and may reach 600° C. The surface layers of atoms deposited at this high temperature must therefore contract as they cool to the temperature of the bulk of the cathode, and this will give rise to the tensile stresses generally found in electrodeposits. He explains compressive deposits on the basis of co-deposition of non-metallic material. Whether this theory will be proved valid remains to be seen, but it is certainly more embracing than any of the earlier ones.

The Basis Metal

No systematic work has been done on the effect of the basis metal on tensile strength, hardness and ductility of the deposited metal, although indications are that as far as nickel is concerned deposition on either polished copper, brass or steel makes little difference. However, it is interesting to note that internal stress can definitely be influenced by the condition of the basis metal as has been shown by Brenner and Senderoff,[15] Van der Sommen[16] and Pick.[17]

PHYSICAL PROPERTIES OF SOME COMMONLY DEPOSITED METALS

The influence of both the solution composition and operating conditions on the physical properties of some of the commonly deposited metals will now be considered. Unfortunately, there is a scarcity of information on most metals, nickel and chromium being exceptions.

Chromium

The physical properties of chromium deposits have been the subject of much investigation. When attempting to find such values for other electrodeposited metals, an extensive and often fruitless literature search is involved, whereas the main difficulty with chromium is how to summarise the multitude of results which have been obtained.

All investigators are agreed that electrolytic chromium —however obtained—is very brittle. If any elongation occurs before fracture, then it must be less than 0·1%.

The hard chromium plating used for engineering is no harder than that employed at much lower thicknesses for decorative purposes. In fact, all the results go to show that the brighter the deposit the harder it will be. The operating conditions that give a satisfactory bright plate could, therefore, be used for hard chromium giving deposits of about 1,000 V.P.N., although higher temperatures and current densities are usually employed for deposition of thick chromium plate. Dull deposits may have hardnesses as low as 450 V.P.N. Solutions containing fluorides will normally give somewhat harder chromium deposits than those obtained under the same operating conditions from the straight chromic acid/sulphuric acid bath.[18]

The great hardness of electrolytic chromium has been explained as being caused by the occlusion of hydrogen evolved at the cathode during the inefficient plating process. However, if the plate is heated to 400° C., nearly all the hydrogen is removed, but the hardness is not greatly reduced. A more probable theory has been put forward by Brenner[19] based on the hardening effect of chromic oxide inclusions. Certainly, many of the physical properties of chromium plate can be directly related to the oxygen content, although this is by no means precise, possibly because the small grain size of the metal is another factor.

Although the tensile strength of chromium deposited electrolytically can be varied within a wide range by modifying the plating conditions, the metal obtained

under standard bright conditions has a fairly constant tensile strength of between 15,000 and 20,000 lb./sq. in.

The internal tensile stress in chromium deposits rises extremely rapidly with thickness, and increases up to values as high as 180,000–200,000 lb./sq. in., until the chromium first cracks to relieve this stress. This cracking occurs at about 0·0001 in. under normal bright plating conditions, but if the temperature of the plating solution is increased, " crack-free " chromium is produced which does not crack until thicknesses of the order of 0·0008 in. are reached.[20] Once the chromium has cracked, the total stress in the deposit gradually drops, and under some conditions may actually become compressive.[21] It has been suggested that chromium deposited in the cracks already present in the plate introduces expansive forces which overcome the tensile stresses, although this mechanism seems unlikely. Chromium in a state of compressive stress is not obtained at thicknesses less than 0·002 in. The stress in the plate being obtained from any particular chromium solution alters with the plating conditions : for example, increasing the current density increases the tensile stress, while raising the temperature lowers the stress.

Copper

The normal copper sulphate-sulphuric acid bath produces plate with a hardness of about 50–60 V.P.N. and a ductility of about 20–40%, depending on the purity of the solution. The internal stress in the deposit is normally nearly zero. If gelatine is added to the solution as a grain-refiner, the stress becomes highly tensile, and the ductility, as measured by the elongation, drops to about 2–3%. If a bright copper plating solution is produced by the addition of molasses and thiourea to the copper sulphate, then the bright plate produced is brittle (with an elongation of 3%) and correspondingly hard (170 V.P.N.)[22]

Deposits obtained from copper fluoborate-fluoboric acid solution have about the same hardness as those from the acid copper sulphate bath, but are somewhat less ductile, having an elongation of only about 11–18%.

Copper pyrophosphate solution deposits metal with a hardness of 160–190 V.P.N. and approximately 10% elongation. The addition of a proprietary organic levelling agent to this solution produces a more brittle copper plate.

Copper cyanide solutions give deposits of 100–160 V.P.N. with excellent ductility. (30–50% elongation). The use of P.R. current with cyanide baths results in a harder and much less ductile copper plate of 150–220 V.P.N. hardness and 6–9% elongation. One proprietary bright cyanide copper process, which uses an inorganic addition agent, is known to give deposits which are very ductile, although they have a hardness of about 170 V.P.N.

Nickel

The physical properties of nickel electrodeposits can be varied within very wide limits. The dull Watts type of solution, when in a pure condition, will give the softest and most ductile deposits with elongations of 30%, tensile strengths of 60,000 lb./sq. in., and a hardness of 150 V.P.N. This is true provided that the *p*H of the solution is below 5 : increasing the *p*H above this value drastically lowers the elongation to about 5% and raises the hardness to about 300 V.P.N., due to the co-deposition of basic material. The chloride content of the solutions is also important. According to Brenner,[13]

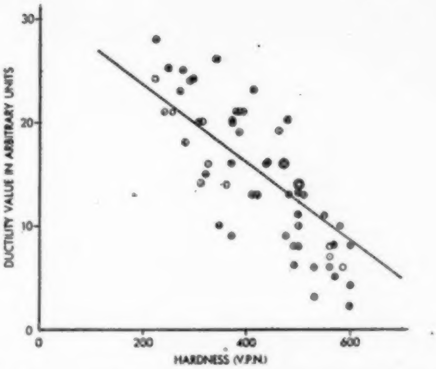


Fig. 2.—Relation between ductility and hardness of nickel deposits.

nickel of minimum hardness and maximum elongation is obtained from a nickel sulphate/nickel chloride solution in which 25% of the nickel is present as nickel chloride. This solution gives nickel with a hardness of 160 V.P.N. and 28% elongation, as compared with a deposit of 240 V.P.N. hardness and 20% elongation obtained from a solution containing nickel sulphate and no chloride.

It should be noted that the elongation or ductility of nickel deposits will always rise as the hardness is reduced and vice versa, as can be seen from Fig. 2, which shows this inverse relationship. This graph has been compiled from ductility and hardness determinations performed on seven types of nickel plating solutions, of which two were dull—a Watts, and an all chloride solution being used—two were proprietary organic semi-bright processes, and three were fully bright solutions, one of these being cobalt-nickel and the other two proprietary baths containing organic additions. In spite of the diversity of nickel baths used, all the results follow the same trend, even if some scatter is present, which necessitated using the method of " least squares " for finding the position and slope of the straight line.

The Watts bath used at its normal concentration :—

40 oz./gal. Nickel Sulphate
7 oz./gal. Nickel Chloride
5 oz./gal. Boric Acid.

will give the most ductile deposits, and increasing the concentration of nickel salts to double these values will reduce the elongation to one third of that obtained with the normal bath. Dull nickel deposits obtained from a bath working at 130° F. exhibit the maximum ductility obtainable, but current density does not appear to have much effect. However, all the effects just discussed —except that of *p*H—are of minor importance compared with the effect produced by small amounts of chemicals, either inorganic or organic in nature, which may be in solution, either as a deliberate addition or inadvertently. The materials used as brightening agents markedly affect the hardness and ductility of the bright nickel plate, as can be seen from Table VII.

Metallic impurities will lower the ductility of dull nickel deposits, but have even more effect on bright nickel. Of the common metals—iron, copper, zinc, lead and chromium—chromium is the most dangerous. The organic type of impurity usually produces a marked drop in ductility, even when present in very low concentration. The sources and chemical nature of organic chemicals that may be introduced into a plating solution

TABLE VII—THE EFFECT OF ADDING PROPRIETARY ORGANIC BRIGHTENERS TO A WATTS NICKEL SOLUTION

Solution	Appearance of Deposit	Proprietary Process 1		Proprietary Process 2		Proprietary Process 3	
		Ductility	Stress (lb./sq. in)	Ductility	Stress (lb./sq. in)	Ductility	Stress (lb./sq. in)
(A) Watts nickel	Dull	18	36,100 (tensile)	55	29,400 (tensile)	45	31,300 (tensile)
(B) Secondary brightener added to (A)	Semi-bright	13	3,100 (tensile)	13	800 (compressive)	21	13,300 (tensile)
(C) Primary brightener added to (B)	Fully bright	4	17,200 (tensile)	4	4,600 (compressive)	6	27,800 (tensile)

are manifold, but almost all of them, including the breakdown products of the organic brighteners have an embrittling and hardening effect on the nickel.

The tensile stress in dull nickel deposits lies between 20,000 and 40,000 lb./sq. in. To keep the stress at a minimum value, the chloride content of the solution should be kept as low as possible, for the stress increases linearly with the chloride concentration (Fig. 3). The pH of the bath must also be maintained below 5. As far as the operating conditions of plating are concerned, to obtain minimal stress values the current density must be maintained at not less than 25 amp./sq. ft. at a temperature of 130° F., although the current density, unless it falls below 10 or rises above 100 amp./sq. ft., does not exert much influence.

Again, the main influence on the stress is exerted by the composition of the solution rather than any other factor. The organic bright nickel solutions are formulated so as to give deposits with very low tensile stress, or even compressive stress. This is done by adding organic chemicals which have a marked effect on stress reduction, such as saccharin, to the proprietary brightening salts. This means that fully bright organic nickel deposits will have lower stress than the nickel obtained from the Watt's solution used as base (see Table VII). However, cobalt-nickel alloy deposits are more stressed than dull nickel, with tensile stresses of between 40,000 and 60,000 lb./sq. in.

While some organic materials may decrease the tensile stress, the majority of those which are accidentally introduced into the solution have the opposite effect. The author has personally known of a tensile stress of over 100,000 lb./sq. in. caused by a substance which was dissolved off a filter medium and could only have been present in a low concentration. Metallic contaminants invariably increase the tensile stress in the nickel plate, although the effect is not marked when the metal is in low concentration in the solution.

The above remarks on the effect of organic and metallic impurities apply equally to nickel baths based on the sulphamate radical. However, the deposit from the basic sulphamate solution is superior to that from a Watts type bath, as it is nearly without tensile stress (1,000 lb./sq. in.) while still being just as ductile (20–30% elongation).[23, 24] Addition of chloride to the nickel sulphamate solution, while it does not increase the hardness of the nickel obtained, which is still of the

TABLE VIII—HARDNESS OF TYPICAL ZINC DEPOSITS.

Type of deposit	Hardness (V.P.N.)
Acid zinc (dull)	47
Cyanide zinc (dull)	41
Cyanide zinc (bright)	53

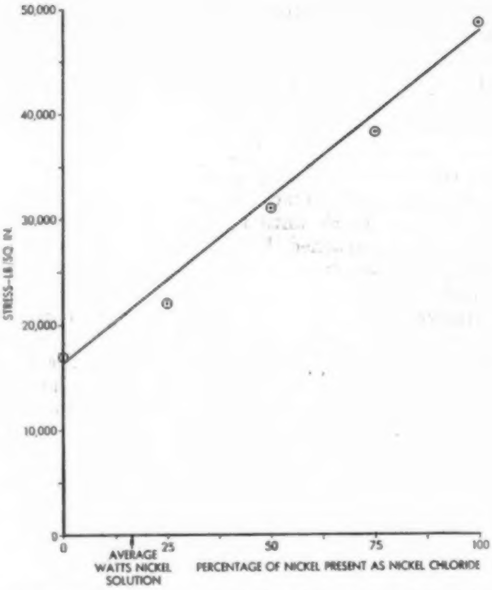


Fig. 3.—Variation of stress of nickel deposits with chloride content of plating solutions. (Brenner, Zentner and Jennings.)

order of 250 V.P.N., reduces the ductility to about 5% elongation and increases the stress to 10,000–15,000 lb./sq. in.

Zinc

Dull zinc deposits normally have a hardness of 40–50 V.P.N. This hardness is increased a little if brighteners are added to the solution. Typical results are given in Table VIII. Tests have shown that zinc deposits from acid solutions are about twice as ductile as those from a cyanide zinc solution, although surprisingly there does not seem much difference between dull and bright cyanide deposits in respect of ductility.

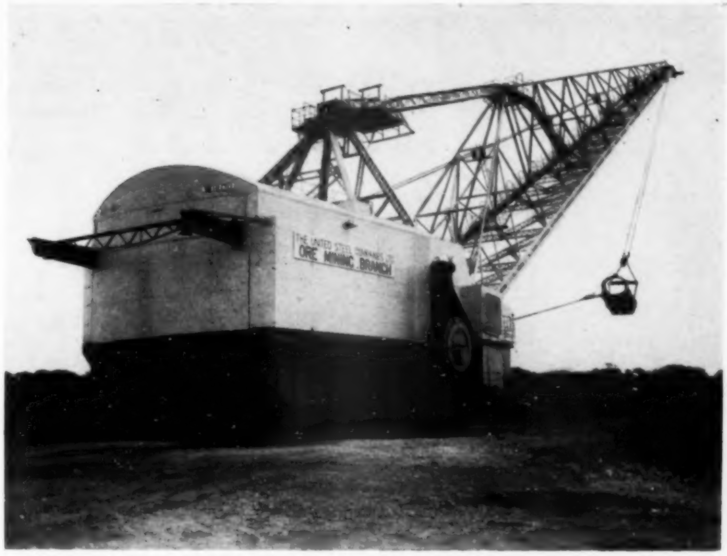
(to be continued)

REFERENCES

1 Macnaughtan, D. J. and Hothersall, A. W., *Trans. Faraday Soc.*, 1935, **31**, 1168.
2 Graham, A. K., *et al*, "Electroplating Engineering Handbook," Reinhold Publishing Corporation, New York, 1955, 339.
3 Ministry of Supply (Armament Research Department), A.R.D. Electrodeposition Memorandum No. 2 (Method of Repair of Worn or Overmachined Steel Components by Electrodeposition of Nickel), H.M.S.O., London, 1946, 7.
4 Almen, J. O., *Product Engineering*, 1951, June, 109.
5 Williams C, and Hammond, R. A. F., *Trans. Inst. Met. Finishing*, 1955, **32**, 85.
6 Stareck, J. E., Seyb, E. J. and Tulumello, A. C., *Plating*, 1955, **42** (11), 1935.
7 Spiro, P., *J. Electrodepositors' Tech. Soc.*, 1948, **23**, 13.
8 Marchese, V. G., *J. Electrochem. Soc.*, 1952, **99**, 39.
9 Such, T. E., *Trans. Inst. Metal Finishing*, 1954, **31**, 190.
10 DuRose, A. H., Karash, W. P., and Willson, K. S., *Proc. Amer. Electroplaters' Soc.*, 1950, **37**, 193.
11 Miller, R. D., and DuRose, A. H., *Proc. Amer. Electroplaters' Soc.*, 1947, **34**, 281.
12 Faint, H. and Modjeska, R. S., *Proc. Amer. Electroplaters' Soc.*, 1955, **41**, 262.
13 Brenner, A., Zentner, V. and Jennings, C. W., Amer. Electroplaters' Soc. Research Report No. 20, Physical Properties of Electrodeposited Metals (the effect of plating variables on the structure and properties of electrodeposited nickel), 1952, 63.
14 Wilman, H., *Trans. Inst. Metal Finishing*, 1955, **32**, 281.
15 Brenner, A. and Senderoff, S., *Proc. Amer. Electroplaters' Soc.*, 1948, **35**, 53.
16 Van der Sommen, J., Proc. Third International Conference on Electrodeposition, 1947.
17 Pick., H. J. *Trans. Inst. Metal Finishing*, 1955, **32**, 128.
18 Morriset, P., *et al*, "Chromium Plating," Robert Draper Ltd., Teddington, 1954, 149.
19 Brenner, A., Burkhead, P. and Jennings, C. W., *Proc. Amer. Electroplaters' Soc.*, 1947, **34**, 32.
20 Fry, H., *Trans. Inst. Metal Finishing*, 1955, **32**, 107.
21 Stareck, J. E., Seyb, E. J. and Tulumello, A. C., *Plating*, 1954, **41**, 1171.
22 Gray, A. G., *et al*, "Modern Electroplating," Chapman and Hall, Ltd., London, 1953, 240.
23 Barrett, R. C., *Plating*, 1954, **41**, 1027.
24 Diggin, M. B., *Trans. Inst. Metal Finishing*, 1955, **31**, 243.

Walking Dragline for Opencast Ironstone Quarry

1,700 ton Monster Starts Work



General view of the W1400 walking dragline.

ONE of the world's largest walking draglines, weighing 1,675 tons and equipped with a 282 ft. long tubular steel jib, has just begun work at an opencast ironstone quarry near Stamford operated by the Ore Mining Branch of The United Steel Cos., Ltd. This £800,000 machine is employed to strip the overburden from the ironstone, which is subsequently loaded by excavators and transported 75 miles by rail to the iron works of Appleby-Frodingham Steel Company in Scunthorpe.

20,000 Tons a Week

Taking 30-ton bites at the overburden, the W1400, as it is called, is expected to strip 20,000 tons of ironstone each week, initially. The actual rate of stripping is, however, dependent on the thickness of the overburden, which at the Exton Park quarry will increase gradually to between 80 and 90 ft., most of which is limestone. In these conditions, about 10,000 tons of ironstone will be stripped every week. The iron content of the ironstone at the 3,000-acre quarry is 30% and it is estimated that it will take about thirty years to work out.

General view of superstructure with 20 cu. yd. bucket in foreground.

Designed and built by Ransomes and Rapier, Ltd., the W1400 is electrically driven, taking power from the mains supply at 6,600 volts A.C., through a trailing cable, to feed two 1,500 h.p. motor generator sets. These sets in turn supply direct current to the 14 main driving motors, each of 225 h.p. The machine is equipped with Ward Leonard Amplidyne control. All the electrical equipment is housed in a spacious motor room, which is serviced by a 25-ton overhead crane.

The revolving superstructure of the machine is supported on a 48 ft. diameter circular base of structural steel, which carries the main roller path, the rotate rack, and the 2 ft. 4 in. diameter steel centre post. The roller path, which is made up of 32 cast segments in nickel-chrome-molybdenum steel, is of heavy bridge rail section and has a mean diameter of 47 ft. This roller path carries a live ring of 120 tapered rollers. The rotate rack consists of cast steel segments with machine-cut teeth, the complete rack having 208 teeth of 6 in. circular pitch and 1 ft. 7½ in. deep.

The revolving superstructure, which carries the jib "A" frame structure and all the machinery for the hoist, drag, slow and walking motions, has a tail radius of 68 ft. 6 in. and a width over the house of 49 ft. The main frame of the superstructure consists of four full-length longitudinal girders, with transverse bulkheads and cross girders and a bridge girder extending the full width of the frame to carry the heavy loads from the walking mechanism. Some idea of the immense size of the machine is gained from the dimensions of the four longitudinal girders, each of which is 14 ft. deep by 75 ft. 9 in. long.

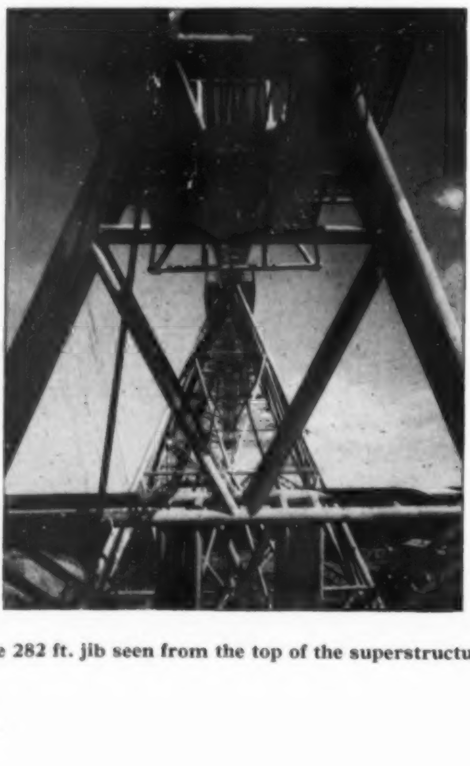
Walking Gear

The patented walking gear which enables the W1400 to walk in a series of steps in any direction has many special features to ensure its complete reliability. There are two walking shoes, one on each side of the house,

A saloon car can be driven into the 20 cu. yd. bucket with adequate clearance.

each 48 ft. long by 9 ft. 6 in. wide, carried on vertical legs which are driven by eccentrics. The walking operation is carried out by lifting and tilting the entire machine so that it slides across the ground to a new position, having made a step of 6 ft. 10½ in. The weight of the machine is carried on hollow stub axles forming part of the bridge girder, thereby transmitting the weight of the machine direct to the superstructure, and not through the driving machinery. The driving shafts, subject to torsional stresses only, pass through the axles to the eccentrics; these are filled with rollers which run in machined paths in the legs. The connection to the shoes is by ball and socket joints, giving free movement for the shoes to accommodate uneven ground.

The hoist and drag machinery consists of two complete winding units identical in design excepting for the grooving of the winding barrels. Each unit is driven by four motors, each of 225 h.p., through balanced gear reductions to the main winding drum. The drums are grooved for winding two ropes in right and left hand grooves. With the Ward Leonard Amplidyne control, no operating brakes or clutches are required, but electro-magnetic parking brakes are provided on each motor.



The 282 ft. jib seen from the top of the superstructure.

The maximum pull on each winding barrel is 100 tons, and the rope speeds range from 290 ft./min. at normal full load to 513 ft./min. at no load. The rotate motion is driven by two gear units each with its own 225 h.p. vertical motor. The rotating speed is at the rate of 1¼ r.p.m. which gives a jib head speed of 2,000 ft./min. or nearly 23 miles/hr. The torque about the centre post reaches a maximum of 7,032,000 lb. ft. It takes approximately one minute to complete a cycle of digging, slewing, dumping and returning the machine to its original position.

Welded Tubular Jib

The great jib is of all-tubular welded construction, triangular in section, with two double tube compression members and one double tube tension member. A tubular structural suspension member connects the jib through safety links to the head of the "A" frame, but the jib may be lowered to the horizontal position, for which purpose a jib hoist winch operating ten parts of rope is fitted. In normal working order, the jib is supported by a tubular steel suspension member, and is not dependent on jib hoist ropes except for adjustment to the working angle and for lowering to ground level.

The drag bucket is of 20 cu. yd. capacity and is of all-welded construction with renewable teeth. Digging 30 tons of overburden at each bite, the W1400 can shift its own weight of material every hour, dumping it up to 260 ft. away and at a height above ground level of up to 120 ft.

Two driving cabins are provided, one well forward on each side of the machine so that the driver may occupy whichever gives the better vision for the work in hand. The machine is controlled by one man who sits in armchair comfort with all controls mounted in a console unit beside him.

The whole superstructure house is pressurised by means of air filtering and fan equipment. This serves the dual purpose of ensuring an ample supply of cool air for the electrical equipment and preventing the admission of dust. Passages with airlocks are provided for access to the various parts of the machine.

Birlec Dryers for Nuclear Power Plants

Birlec, Ltd., announce that they have recently received orders for air- and gas-drying equipment for three nuclear power plants. At Berkeley, in Gloucestershire, and at the station to be built in the South of Scotland, their purpose is to prevent condensation and consequent corrosion taking place in carefully prepared gas systems. In the Dounreay reactor, an alloy of sodium and potassium is used as the heat transfer medium, and although every precaution has been taken to prevent any leakage, it is essential that, should any metal escape, there is no condensation in the reactor sphere that might lead to an ignition or even an explosion that could seriously damage the reactor.

Continuous Stress-Relief of Transformer Laminations

Fig. 1.—Charge end of continuous stress relieving furnace.

THERE is an increasing demand in industry for continuous processes to replace batch production. The industrial furnace designer is therefore constantly reviewing established practice to see whether improvement is possible. A good example of the results achieved by such reconsideration is the process of stress-relieving cold-rolled silicon steel transformer laminations.

For some years it has been standard practice, after the stamping operation, to stress-relieve the laminations in a lift-off furnace. One of the requirements in the manufacture of these stampings is a high space factor: buckling and "rivelling" of the edges of the sheet are bound to make a bulky transformer. The lift-off furnace has normally been used for the heat treatments since it allows the careful placing of packs of lamination, which are then left undisturbed throughout the heating cycle.

Careful consideration, however, shows that the lift-off furnace has several serious disadvantages. The first and most obvious is that it is a batch method, but it is also evident that considerable difficulty is experienced when loading the furnace. The stampings vary in length and width, and production methods are such that there is very seldom a furnace load of one size of stamping. Great skill and care are therefore necessary to fit the greatest number of stampings on the furnace base, while allowing good heat transfer to the load and avoiding distortion of the stampings.

Again, even if production methods were such as to give a large number of the same size laminations at the same time, it would be undesirable to have an unbroken stack of stampings reaching the full piling height of the furnace, since heating up and cooling would be extremely slow. This difficulty cannot be overcome by increasing the heating rate, because of the danger of serious distortion of the sheet, due to the heat being transferred through the edges of the packs. In this way, the edges reach soaking temperature while the centre is still comparatively cold, and expand relative to the centre, thus setting up severe strains which result in wavy edges and, in extreme cases, buckling of the whole sheet. The adoption of a slow heating and cooling cycle does not completely cure this trouble, although it does reduce it to some extent. In practice, steel spacer pieces are placed every six to eight inches to separate the packs and allow heat transfer vertically as well as inwards from the edges. The next pack is then supported on a steel plate to reduce distortion, so that a considerable weight of steel is uneconomically heated in each cycle. To ensure complete soaking of the stampings, the spacer pieces, and the furnace cover requires a 45–50 hr. cycle.

This length of cycle brings a further difficulty. Carbon is an undesirable impurity in electrical sheet, and the manufacturer aims at reducing it to a very low level: certainly below 0·008%. Such sheet is, of course, highly susceptible to carbon pick-up during heat treatment; the atmosphere must therefore be non-carburizing, and an atmosphere derived from cracked and burnt ammonia —not the cheapest of atmospheres—is required for a lift-off furnace. On many counts then, the traditional method seems far from ideal, and Metalectric Furnaces, Ltd., Smethwick, who have built a considerable number of lift-off furnaces, were led to the conclusion that the continuous furnace might well have many points in its favour. Several advantages seemed possible: (1) a very great reduction in the time cycle could be achieved—always an important point for production schedules; (2) a cheaper form of atmosphere could be used, because the shorter heating time would bring a great reduction in the risk of carbon pick-up; (3) a much better flow of work would be possible because a continuous furnace could be designed to suit the maximum width of sheet, while variations in length, so awkward in the batch method, would be unimportant; and (4) a considerable fuel saving was likely because there would be no spacer pieces and steel plate to heat up.

Accordingly, Metalectric engineers carried out a series of tests on a continuous furnace arranged to use any industrial controlled atmosphere. In this way it was possible to compare the effect of various atmospheres on the physical and electrical properties of the sheet. By arrangement with one of the leading manufacturers of

electrical equipment, matched pairs of test pieces were cut from sheet : one test piece in each pair was stress relieved by the manufacturer's usual method, and the other was heat treated in a continuous furnace. The samples were then tested and compared.

The results showed conclusively that the long cycle lift-off process was unnecessary. The continuously treated test pieces were much better than those from the batch process as regards physical condition. In electrical tests there was less difference ; nevertheless there was still a slight advantage in favour of the continuous process. The mean losses in watts/lb. of a large number of the batch treated samples were 0·539, 0·536, and 0·542, while the continuous furnace gave 0·523, 0·527, and 0·526. The mean of these figures is 0·539 for the batch and 0·525 for the continuous process.

The next step clearly was to stress-relieve sufficient stampings to build a complete transformer. This was necessary to prove the method, and also to show that the higher heating and cooling rates obtainable in the continuous process have no deleterious effects on the laminations, whether from the physical or from the electrical standpoint. The experiment was completely successful : the laminations were completely flat, and the atmosphere used cost only one-fifth as much as a cracked and burnt ammonia atmosphere.

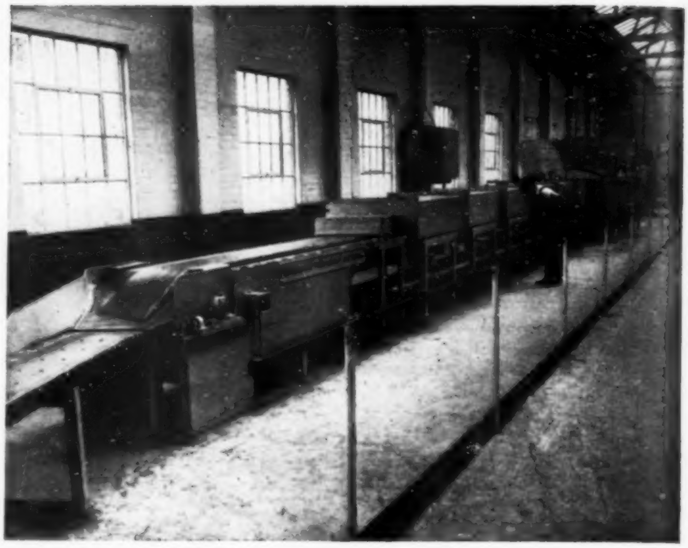


Fig. 2.—Discharge end of the same furnace.

Metalectric Furnaces, Ltd., have now built, or are building, a large number of continuous furnaces for this work, with outputs ranging from 20 to 60 tons/week. Experience gained on these plants has shown that while the total cost of stress-relieving in lift-off furnaces varies between £8 and £10 per ton, in the continuous furnace, the cost is £5-10-0 to £7-10-0 per ton ; a very substantial saving.

A typical furnace for this work is shown in the illustrations (Figs. 1 and 2) : it is installed at the works of The British Thomson-Houston Company at Rugby. The overall length of the furnace is 60 ft., and the heating section has two separately controlled zones. The nickel-chromium tape elements are fitted to the sides and hearth of the chamber, and are rated at 120 kW. Although the normal working temperature is 820° C., the furnace is designed to operate up to 900° C. The cooling section is water-jacketed and is mounted on rollers to allow for expansion. The conveyor is 26 in. wide to handle laminations up to 24 in. wide, and is driven by a variable speed gear. The usual belt speed is 1 ft./min., giving a complete cycle from charge to discharge of 1 hr., compared with the 40 hr. or more of the batch process. Output at this speed is 450–500 lb./hr.

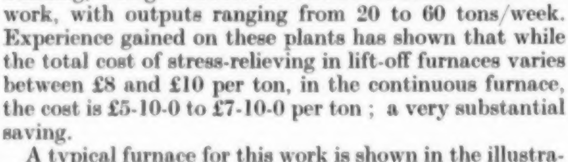


Fig. 3.—Hi-Nitrogen plant of 1,000 cu. ft./hr. capacity.

The laminations are loaded directly on to the conveyor in shallow packs ; there is thus a much greater heat transfer rate in this furnace than obtained in the lift-off furnace with its thicker packs. The packs travel through an inlet canopy designed to reduce controlled atmosphere losses, then through a vestibule which acts as a heat seal, and so through the regulated heat and soak zone, the cooling zone and the outlet canopy, on to a roller conveyor. Power consumption on this furnace is only 15·2 kWh./cwt. of work processed, i.e., 304 kWh./ton.

The protective atmosphere is supplied by an Incandescent Hi-Nitrogen plant producing 1,000 cu. ft./hr. of nitrogen (Fig. 3). Air is inspirated and mixed with sufficient fuel (in this case town's gas) to give complete combustion and thus remove the free oxygen in the air. The products of combustion are then bubbled through monoethanolamine, which absorbs the carbon dioxide, and the remaining gas is passed through a dryer to remove the water vapour and leave dry nitrogen. In normal operation, a dewpoint of −30° F. is consistently obtained ; lower dewpoints can be obtained if necessary.

Kent Office in Bangkok

Direct representation in Thailand has been established by George Kent, Ltd., in a drive to increase exports into the South-East Asian area by meeting the growing demand in that country for measuring and control apparatus. A Kent Branch Office and Workshop has now been inaugurated in Bangkok, as an offshoot of George Kent (Malaya), Ltd. The address of the Bangkok Branch is 284/1, Suriwongse Road.

Strain-Ageing as an Explanation of the 'Knee' in the Fatigue Curve of Mild Steel

By John C. Levy, M.S., B.Sc.(Eng)

Lecturer, Civil and Mechanical Engineering Department, Northampton Polytechnic, London, E.C.1

The author discusses the effect strain-ageing may have on fatigue life. An explanation is offered of the sharp "knee" and well-defined fatigue limit in the S-N curve of mild steel by postulating two such curves—one for the non-strain-aged material and another for the fully strain-aged material. Transformation from one to the other by strain-ageing during the test can then produce the "knee" in the curve. This concept is shown to be consistent with reported experimental results.

THE meaning of the term strain-ageing is often illustrated by the conventional tensile overstrain test. The phenomenon is most marked in those materials which exhibit a sharp yield point in their stress-strain curves, and Fig. 1 shows a typical set of results obtained on a specimen of mild steel.

There is a sharp yield at A, and continued straining causes work hardening to B. If the load is now reduced to zero the curve BC is obtained, and should the load be immediately reimposed the hysteresis loop $BCDE$ is formed, plastic deformation continuing at almost the same stress as that at which the test was interrupted. If, however, the material is left unstressed at C for a sufficient time and is then re-loaded, a sharp (and elevated) yield point is once more observed as shown in Fig. 1*b*.

Increased hardness, increased tensile strength and decreased ductility accompany this raising of the elastic limit, and these effects, when obtained in this way, are said to be due to "strain-ageing." The phenomenon is by no means of theoretical interest only. If, for example, in the pressing of steel sheets it is important that the markings known as "stretcher-strains" should not appear, the sharp yield point must be eliminated by "roller levelling" immediately prior to pressing.[1]

The Mechanism of Strain-Ageing

The theory of strain-ageing due to Cottrell is now fairly well known and is described in Reference 2. Briefly, the effect has been traced to the action of carbon and nitrogen atoms which tend to congregate at imperfections (dislocations) in the iron lattice. If crystal slip is regarded as a consequence of the movement of dislocations, it will be necessary, before slip can occur, for the binding forces between dislocations and the nearby carbon and nitrogen atoms to be overcome. However,

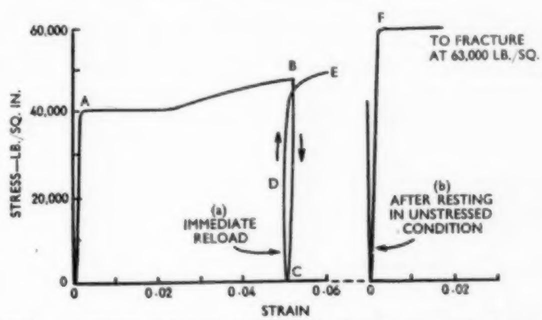


Fig. 1.—Strain ageing of mild steel in interrupted tensile test.

once this *has* occurred, a smaller force will be sufficient to continue the movement of freed dislocations, and this can be shown to account for the unusual yield point behaviour associated with materials capable of strain-ageing. In Fig. 1 the yield point recurs at F because resting at C allows time for the solute atoms to diffuse, and so to re-anchor the dislocations. The longer the time spent at C the more obvious is the return of the yield point, as shown in Fig. 2 from the work of Griffis, Kenyon and Burns.[3] Being the product of a diffusion process, it is to be expected that strain-ageing is temperature- as well as time-sensitive. In confirmation of this, it has been found that resting at a mildly elevated temperature, say at the boiling point of water, greatly accelerates the return of the yield point.

Thus the salient features of strain-ageing, in-so-far as it concerns the present discussion, are :—

(1) that it is an effect which follows plastic deformation of the metal ;

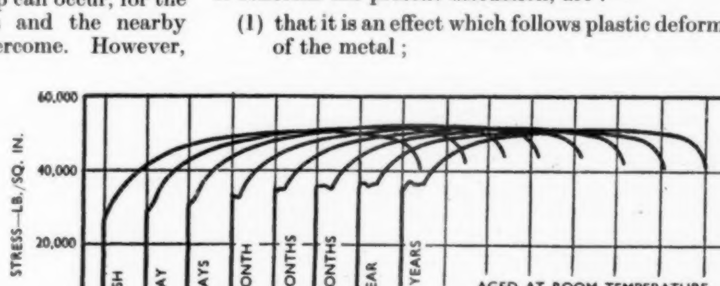


Fig. 2.—Return of jogged stress-strain curve during ageing after straining by cold-rolling 1%

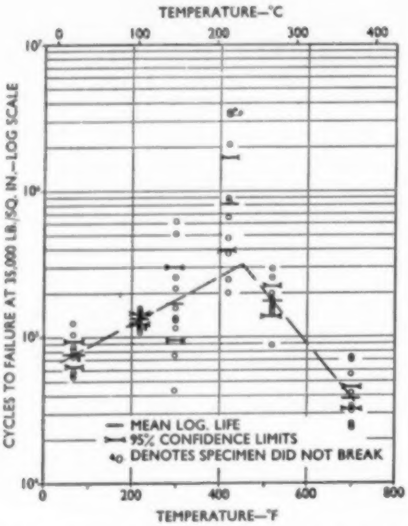


Fig. 3.—Fatigue results of low carbon steel up to 400° C.

(2) that it raises the elastic limit ; and

(3) that it is a diffusion process and, therefore, both time- and temperature-sensitive.

Strain-Ageing During Fatigue

During the process of fatigue, plastic deformation occurs in highly localized regions. It is to be expected therefore that, if a material is capable of strain-ageing, it will do so in those deformed regions when subjected to repeated loading. Moreover, since fatigue usually takes place over a relatively long period, there will be time available for strain-ageing significantly to affect the progress of damage. This was first pointed out by Sinclair[4] in 1952, during a study of the " coaxing " phenomenon.* He observed that those materials capable of strain-ageing could be coaxed to much higher fatigue strengths than they formerly possessed. This he attributed to the raising of the elastic limit by progressive strain-ageing of the " weakest spots."

Subsequently, Levy and Sinclair[5] carried out a programme of work specifically aimed at isolating the effect strain-ageing has on fatigue life. Use was made of the temperature-sensitivity of the ageing process, some results being depicted in Fig. 3. It was shown that the temperature at which the peak life occurred agreed well with the temperature calculated on the assumption that, in order to re-anchor dislocations after plastic flow in fatigue, carbon and nitrogen atoms have to be able to diffuse a distance of 2×10^{-6} cm., during one loading cycle. This is approximately the distance these foreign atoms have to travel during strain-ageing after tensile overstrain.[6]

It may therefore be deduced that if plastic flow occurs in a zone during a particular load cycle, the most favourable condition is reached when the elastic limit can be raised by strain-ageing in that zone during the *same* load cycle Furthermore, the experimental results indicated that the progressive removal of carbon and nitrogen from the material also removed the tendency for a peak to occur in fatigue life. Thus the effect could properly be classified as one due to strain-ageing.

* By coaxing is meant the application of a large number of cycles (say 20 million) at a stress just below the fatigue limit, followed by another 20 million cycles at a slightly higher stress and so on at progressively increasing stress levels.

The ' Knee ' of the S-N Curve

It may be argued that for practical purposes the majority of common metals and alloys exhibit a fatigue limit when tested in non-corrosive conditions. The difference between soft steels and most other metals is that the steels approach their fatigue limit suddenly, whereas the other metals appear to approach theirs gradually.

Admittedly, in these latter cases, the asymptote may be at an extremely low stress. Nevertheless, it does seem reasonable to assume that a finite reversed stress exists below which not even the largest or most unfavourably oriented crystal would deform other than elastically. Inspection and extrapolation of the fatigue curves for many non-ferrous metals reveals that, in most cases, the S-N plot becomes so flat by about 10^{10} cycles that if the stress be lowered still further the probability of failure becomes virtually zero.

What, then, is the fundamental metallurgical difference between those metals which approach their fatigue limit suddenly and those which do so gradually ? In answer to this question it has recently been suggested[7] that materials possessing a sharp knee in their S-N curve are also those which are capable of strain-ageing during a fatigue test. Into this category fall mild steel and certain titanium alloys.[8] It will be noted that steels with high carbon contents do not always appear to exhibit a knee in their S-N curves and neither do they strain-age in a tensile test as readily as does mild steel.

Rally and Sinclair[7] have shown that the position of the knee alters as conditions for strain-ageing become less or more favourable. A selection* of their results is shown in Fig. 4. By statistical analysis it is established as a valid conclusion that, as the temperature increases, so the knee moves to the left. This is consistent with the idea that in a fatigue affected zone ageing will occur more rapidly (i.e. in fewer cycles) at higher temperatures.

It is possible however to carry the argument further than this. Let us postulate, as in Fig. 5, two S-N curves AA' and BB' for the same material in the strain-aged and non-strain-aged conditions, respectively. That is to say, material B is identical to material A, except that the capacity of material B to strain-age has been removed by some means.

Suppose now that a fatigue test is conducted on an annealed sample of material A at the high stress S_1. The

* Results at room temperature have been omitted since these were obtained on a different machine.

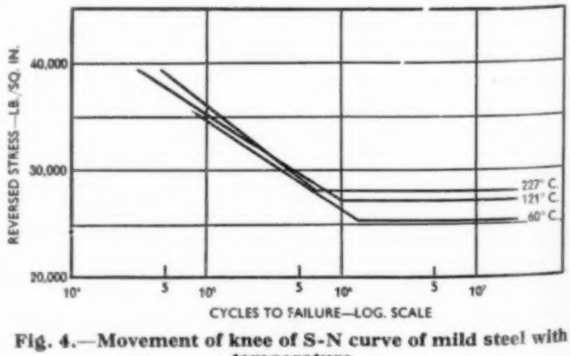


Fig. 4.—Movement of knee of S-N curve of mild steel with temperature.

fracture point will be at D, since there will be no time for strain-ageing significantly to affect the progress of fatigue damage. However, if the low stress S_4 is employed then before the fracture point E is reached, strain-ageing converts the material into that represented by curve AA', which means that no fracture will occur at S_4. The existence of the sharp knee may then be accounted for as follows :—

For lower values of stress than S_1 the S-N curve will follow a path such as DK, since, even in the finite-life range, strain-ageing during the test will result in a somewhat prolonged endurance. (Experimental confirmation of this is deducible from the results of Fig. 3.) The mechanism may be pictured as one by which strain ageing strengthens a certain proportion of the " damage-nuclei " formed at any particular stress level.

As the stress is reduced towards S_4, a point is reached abruptly at which *all* the damage nuclei are strengthened, the material being transformed into that which gives the curve AA'. If this critical stress level is S_3, the observed S-N curve will be DFC, a knee occurring at point F.

Were the tests conducted at a mildly elevated temperature, conversion to the fully-aged material would be possible at a somewhat higher stress than S_3, say S_2. The S-N curve would then become DGH and the knee have moved upward and to the left. It will be seen that this is consistent with the experimental results shown in Fig. 4.

In a case where strain-ageing is fully effective at a stress appreciably above the asymptote at A', a kink should be formed in the S-N curve, which might then follow a path such as $DKLA'$. While no example of this is known in conventional fatigue testing, it is possible that for a value of S_3 only slightly greater than A', the effect has been masked by the large amount of scatter in the vicinity of the endurance limit, and by the statistical nature of the limit itself.

In point of fact, a kink such as $DKLA'$ is relatively easy to form in the curve for mild steel if the stressing is interrupted by rest periods to allow strain-ageing to occur. Bolenrath and Cornelius[10] have reported that the life may thus be increased by a factor of 100. In contrast the lives of metals which cannot strain-age are quite unaffected by similar rest periods.

Referring again to Fig. 4, the authors[7] have illustrated how the actual number of cycles to the knee at different temperatures may be compared with the theoretical number if the carbon and nitrogen atoms have to diffuse 2×10^{-6} cm. in order to cause strain-ageing. The comparison is shown in Fig. 6, and it will be seen that the

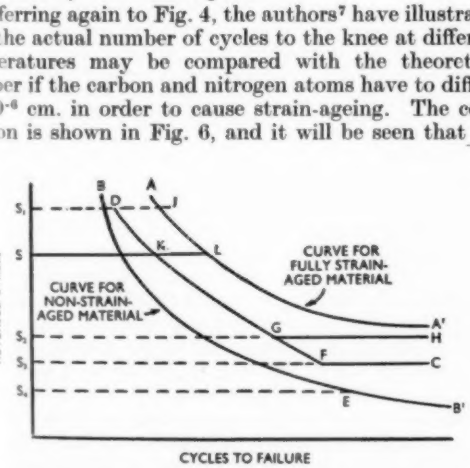


Fig. 5.—Schematic diagram to explain the formation of knee in the S-N curve of strain-ageing material.

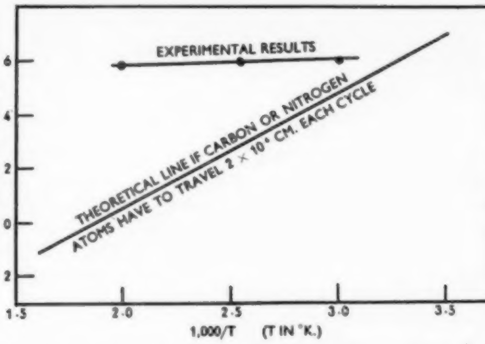


Fig. 6.—Comparison of theoretical and actual cycles to form knee in S-N curve of mild steel.

agreement is not all all satisfactory. However, in plotting the theoretical line, it was assumed that strain-ageing begins as soon as the fatigue test is started, whereas it cannot in fact begin until some plastic flow has occurred. If such plastic flow is associated with the appearance of slip lines, then it would appear that a fatigue test in the vicinity of the endurance limit may proceed for a considerable number of cycles unaccompanied by strain-ageing. Ewing and Humphrey[11] and Love[12], in metallographic studies, have observed that at low stress ranges slip lines often do not appear before 10^5 or 10^6 cycles have been endured. There is thus some justification for adding say 5×10^5 cycles to the ordinates of the theoretical line in Fig. 6, giving good agreement with the experimental results.

In conclusion, then, it appears that strain-ageing offers evidence of both a qualitative and quantitative nature to account for the existence of a sharp knee in the S-N curves of materials which readily strain-age under tensile conditions. It does not follow, however, that ability to strain-age in a tensile test is a *necessary* condition for strain-ageing to occur in a fatigue test. It may be in some metals fluctuating load conditions could induce metallurgical changes which would allow strain-ageing to occur. A knee might then be observed in the S-N curve, though there may be no indication of a sharp yield point in the conventional tensile stress-strain curve.

REFERENCES

1 Murray, G., " The yield point in steel," *Engineering*, 1954, **178**, 366–369.

2 Cottrell, A. H., " Dislocations and plastic flow in crystals," 1953, Clarendon Press, Oxford.

3 Griffis, R. O., Kenyon, R. L., and Burns, R. S., " The ageing of mild steel sheets," *Yearbook Am. Iron & Steel Inst.*, 1933, **23**, 142–165.

4 Sinclair, G. M., " An investigation of the coaxing effect in fatigue of metals," *Proc. Am. Soc. Testing Mat.*, 1952, **52**, 743.

5 Levy, J. C., and Sinclair, G. M., " An investigation of strain-ageing in fatigue," *Proc. Am. Soc. Testing Mat.*, 1955, **55**, 866–890.

6 Nabarro, F. R. N., " Mechanical effects of carbon in iron." Report of a Conference on the Strength of Solids, Bristol, 1947. Published by the Physical Soc., London.

7 Rally, F. C., and Sinclair, G. M., " Influence of strain-ageing on the shape of the S-N diagram." *T. & A.M. Report No.* 87, 1955, University of Illinois.

8 Romualdi, J. P., and D'Appolonia, E., " Effect of range of stress and pre-strain on the fatigue properties of titanium," *Proc. Am. Soc. Testing Mat.*, 1954, **54**, 798.

9 Korber, F., and Hempel, M., *Mitteilungen Kaiser-Wilhelm Inst. Eisen*, 1935, **17**, 247.

10 Bolenrath, F., and Cornelius, H., " Effect of rest periods on endurance and fatigue strength of metals," *Bull. British Non-Ferrous Metals Research Association*, Sept. 1940, 135.

11 Ewing, J. A., and Humphrey, J. C. W., *Phil. Trans. Roy. Soc.*, 1902, **200**, 241.

12 Love, W. J., " Structural changes in ingot iron caused by plastic and repeated stressing," Rep. No. 33, ONR Contract N6-ori-71 T.O. IV., 1952, T. & A.M. Dept., University of Illinois.

Alloy and Special Steels in Railway Work

By Professor Hugh O'Neill, D.Sc.

University College, Swansea

This paper was originally prepared in response to an invitation from the organisers of a Symposium on Alloy Steels, held at the National Metallurgical Laboratory, Jamshedpur, India, last year. The author refers to applications of alloy steels to the permanent way, to locomotives, and to other rolling stock.

MANY people are concerned about the conservation of metal, especially in these days, when such things as tin cans, razor blades, etc., cause steel to disappear from the recovery cycle. The intelligent use of alloy steels may help in this conservation, provided that they are not employed in a profligate manner, and that alloy elements are not allowed to go to waste in slags. Manganese is one of the most useful elements in steel manufacture, and the present consumption is said to average about 14 lb./ton of ingots.[1]. When steel scrap is remade into ingots, much of this element is lost by oxidation, and already there is anxiety about manganese conservation. Steel-melting processes which would avoid the removal of most of the manganese from the charge are therefore to be welcomed, and one attempt to operate a simple fusion process for fine grain castings has been described.[2] Where current is cheap it is possible that this objective may be achieved in electric furnaces.

In railway work, the extra cost of alloy and special steels compared with plain carbon material must pay for itself by one or more of the following factors :

(*a*) weight reduction of mobile units
(*b*) reduced weight of reciprocating parts of locomotives
(*c*) increased resistance to wear and abrasion
(*d*) increased resistance to corrosion
(*e*) protection against service shock and impact
(*f*) increased endurance (fatigue) limit
(*g*) avoidance of cracking during heat treatment or heating in service.
(*h*) efficient scrap recovery.

The general feature of alloy elements in steels is that during heat treatment they slow down the transformation of austenite to other microstructures, and thus enable hardening and strengthening effects to be sustained right through a large section of metal. If carbon alone is used to give high strength, then the carbon content of large sections is limited by the tendency of plain steels to crack when water quenched.

Precautions on Adopting Alloy Steels

Alloy structural steels may be said to "give their strength easily," in the sense that a given yield or ultimate stress value is accompanied generally by higher ductility and impact resistance. On the other hand, if their "yield ratio" (i.e., yield stress/ultimate stress) is high, then a design based on this higher yield value has a lower plastic range available in case of unexpected overload. It is the long plastic range of good mild steel which makes it such a valuable structural material for everyday knock-about use at normal temperatures. Furthermore, many high tensile alloy steels are relatively notch sensitive, and their fatigue resistance when heat treated to the higher values of ultimate stress may not come up to expectations in service. This applies especially if the surfaces of the steel components become roughened and pitted, or if they are used in the black condition, with patchy scaling and considerable decarburisation. Fatigue test results obtained with highly polished specimens in laboratories should be applied with caution if the working part will be in use with a very different finish. It should also be realised that many alloy steel plates come from the rolling mill with surfaces which are inferior to those of carbon steels.

The designer will realise that although steels may be given increasing yield and ultimate stress values by heat treatment and by alloying, yet the elastic modulus of all steels is about the same. Reduction of section will, therefore, not always be justified if elastic effects are preponderent, for it is no use making a lightweight coach if the doors will not close when it is loaded with passengers. Special designs to secure stiffness will look after this aspect in most structures.

A word of caution must be given about the decreased weldability of many alloy steels. If they are introduced into service where mild steels have hitherto been in use, then great care must be taken to see that unauthorised welding—especially for repair work—does not creep in. The replacement of a metal retaining-clip on an alloy steel connecting rod by a blob of weld metal once wrecked a diesel locomotive as a result of cracking from the brittle weld.[3] In the same way, gas-cutting of alloy steels must be carefully supervised if operators have previously been accustomed to mild steel.[4] With a mention of the words "hairline cracks" and "temper brittleness" enough will have been said to caution engineers who may be changing over from the fabrication of mild steels to those containing considerable amounts of alloy elements.

Locomotives

Limitations of axle loads on track and on bridges have to be considered. Motive power is now provided by diesels, electric locomotives and gas turbines, and these machines contain plenty of special materials. The choice of the steel depends upon the "ruling section" of the structural component from the heat treatment point of view, and increase of section requires increased hardenability of the steel. An insight into the utilisation of alloy steels for steam locomotives may be gathered from such published accounts as that of the L.M.S. high-speed engine[5]. The use of plate for the boiler shell and firebox containing 1·75–2·0% nickel enabled a saving of weight of just over 2 tons with service design based on tensile strength. For a boiler weighing 28 tons on a locomotive scaling more than 100 tons, this is not a large proportion, and in times like the present when nickel is in short supply, it is wiser to use it for other purposes. A good

quality higher manganese steel would suffice. The use of any alloys which might resist strain-age embrittlement or caustic cracking in boiler plate, however, is a point to be borne in mind.

For locomotive frames, the use of a steel with an ultimate tensile stress of 35–40 tons/sq. in. instead of mild steel enabled 17 cwt. to be saved. The low alloy material had a composition of carbon—0·2%, manganese—0·85–1·0%, and chromium—0·45% max., and this was chosen to restrict the hardening which may develop on the burnt edges when the frames are gas-cut to shape. Attention must be paid to the upper corners of the axle box spaces in the alloy steel frameplates, as notch-sensitive conditions may eventually lead to fatigue cracks in service.

Motion Parts

As regards motion parts, the substitution of alloy for plain carbon steels enables reciprocating and revolving weights to be reduced, and a nickel-chromium-molybdenum steel of 50–60 tons/sq. in. ultimate tensile stress saved 1,000 lb. weight compared with a 40–45 ton manganese-molybdenum steel. As the surfaces of motion parts can be machined to and maintained at, a good surface finish, one can expect to obtain fatigue resistance approximating to laboratory tests. At the same time, stress raisers and notch effects must be watched in the design, and shops turning over to the machining of high tensile steels may have to reduce machining speeds and feeds.

The connecting rods of internal combustion engines have to withstand shock effects when detonation occurs. Similarly, coupling rods may be subjected to shock effects if there is slipping of driving wheels, and some engineers specify a minimum notch bar value. This is readily obtained by using alloy steels, but also by employing special steels of the inherent fine grain size type.[6] Grain control is generally secured by careful additions of aluminium, but small amounts of vanadium also produce a similar effect. Results obtained from 4 in × 4 in. sections after quenching in oil from 850° C. and tempering at 625° C. and air cooling are given in Table I.

TABLE I..—STEELS FOR COUPLING RODS.[6]

Ref.	C (%)	Mn (%)	Mo (%)	Ultimate Tensile Stress (tons/sq. in.)	Elongation (% on 2 in.)	Izod Impact (ft. lb.)
A	0·25	1·56	0·30	41·5	27	93
B	0·37	0·98	—	42·6	30	91
Spec.				40 min.	20 min.	60 min.

Steel B was of the inherent fine grain type which most manufacturers can produce. Steel A was satisfactory, but care must be taken to avoid segregation effects in the ingots which might lead to pearlite banding in the forgings. Temperature control in heat treatment for this steel must be close, or fluctuations in Izod value may arise. It is possible that these may be associated with a transformation during heat treatment into the "intermediate" region of the T.T.T. diagram.

Drawgear

Couplings and drawbar hooks may be subject to shocks, and design should avoid severe stress concentrations and notch effects. Surface rubbing and deformation might produce the fine cracks known to exist in worn wrought iron chains, but low carbon steels with manganese contents just over 1%, and inherent fine grain size, give high impact resistance and a low liability to strain-age embrittlement.

Springs

The operation of laminated or coiled springs depends upon Young's modulus, and this is roughly constant for all steels. A high yield point to resist permanent set under load has to be considered, however, and from considerations of suitable sections, a quenched and tempered silico-manganese steel containing carbon—0·5–0·6%, silicon—1·8–2·0%, and manganese—0·7–1·0%, may be attractive. Plain carbon springs require to be water-quenched to give the desired yield point, and the incidence of quench-cracking may be high. The silico-manganese steel is not unduly expensive, and can produce the right yield resistance by oil quenching. This material, however, is generally more prone to scaling and decarburisation during processing, and care should be taken that fatigue cracks do not start in service from these surface defects.

"Elastic spikes" for holding down flat-bottom rails are frequently made of silico-manganese spring steel. Notch damage by corrosion has to be considered in these details.

Tires

Tires deteriorate by (*a*) wear of tread and flange, (*b*) shelling of the tread surface, (*c*) thermal cracking—"heat cracking"—of the tread, (*d*) fatigue cracks from the bore surface, and (*e*) in rare cases, internal fatigue flaws from shatter cracks. Machining to a very high surface finish will prevent fatigue cracks from the bore surface where it mates with the wheel centre.

British Standard Specification No. 24—Part 2 deals with four classes of tires, with ultimate tensile strengths ranging from 42 to 69 tons/sq. in. Only the sulphur and phosphorus contents are specified, as regards chemical composition, and most tires are of plain carbon steel. Izod impact tests on pieces from standard positions generally give low results like 4 ft. lb., and there is something to be said for trying to improve this value. The author[7] has previously pointed out that an initial crack in a rail or tire is less likely to be propagated in service in a steel of high notch bar resistance, and, consequently, it may be observed during routine inspections and the tire removed before complete fracture. Incidentally, for hardened rolls "high carbon-chromium steels are universally used."[8]

To obtain better impact values and greater resistance to wear and thermal troubles, a Rotherham firm has for many years produced alloy steel tires. On the mountain lines in Canada these have given very satisfactory service with a yield point of 50 tons/sq. in. minimum and a composition of carbon—0·70%, chromium—0·5%, and molybdenum—0·2%. For an underground passenger electric railway, tires with a strength of 56–62 tons/sq. in. and a composition of carbon—0·40%, chromium—0·65%, molybdenum—0·45%, and manganese—1·45%, give a minimum Izod impact value of 40 ft. lb. These are cases where service experience suggests the limited use of an alloy steel in preference to plain carbon material.

In adopting alloy steels for tires, one has to consider the possible applications of (*a*) flame hardening of treads and/or flange corners to resist wear, and (*b*) repair of worn flange corners by welding. Alloy steels are more

deep-hardening when subjected to these treatments, but the general effects are complicated.

There are some rather elusive principles which govern the surface crazing of tires, axle journals and rails, and they also probably govern the cracking of hard steels during surface grinding, and the spalling of hardened steel rolls. Volume changes occur in steel during quenching and also during tempering, and the trouble about tires and rails is that the frictional heating cycles are uncontrolled and are repeated many times. A hard martensitic layer develops on the running surfaces of rails and tires, and from cracks which supervene fatigue flaws begin to grow. The latter curve round and may result in shelled patches, if not in transverse fractures.

These heat cracks depend upon (*a*) the composition of the steel, (*b*) its prior treatment (carbide particle size and internal stress), (*c*) thermal cycles and their frequency, and (*d*) segregation, surface seams and non-metallic inclusions. On the analogy of grinding cracks, one avoids high internal tensions, retained austenite, boundary carbide and steelmaking defects. At first glance, it might appear that alloy steels would fare badly, but this liability is offset by various factors which sometimes give net advantages.[9] Thus, lower carbon may be used with alloy additions to provide the required yield point, and this means reduced cracking on chilling. An alloy steel may chill with less acute volume changes and, therefore, may have a lower internal stress. Concentrated martensite cannot form unless carbides go completely into solution, so to this extent relatively large carbide particles are desirable with a low solution rate. Chromium will reduce the speed of diffusion and solution, and austempering and martempering effects may take place more readily than in carbon steels. It has been shown[10] in connection with the phenomenon of "delayed cracking" in steels of about 450 Brinell that some alloy compositions are better than others.

Rails

Rails are required to be hard wearing and to have a low liability to breakages. The normal production practices of British railmakers have been very successful in avoiding hairline or shatter cracks in rails, and wear is perhaps the greatest consideration.

As a result of recent publications, we now know a great deal about the optimum rail steels for resisting wear. Losses must be considered from the point of view of (*a*) side cutting of the head of the rail on curves, (*b*) normal wear on straight track, and (*c*) corrosion-wear effects due to the working atmosphere.

Results for (*a*) based on measurements during 25 years on the sharp curves of the electrified St. Gothard line in Switzerland have been selected[11] and included in Table II.

TABLE II.—RAILS IN THE ST. GOTHARD.

Ref.	Wear index	Brinell Hardness	C (%)	Mn (%)	Cr (%)	Cu (%)	Condition
NMCR	0·138	410	0·31	0·82	1·04	—	Heat treated
KR	0·158	260	0·60	1·55	—	0·19	As rolled
VT	0·291	270	0·73	0·74	—	0·21	As rolled
KO	0·296	330	0·80	0·70	0·77	0·4	Compound rail
Normal	1·96	210	—	—	—	—	As rolled

The chromium rail with a structure of tempered martensite has given the best wear result, but such rails are expensive. Otherwise an eutectoid rail containing not more than 1·5% manganese appears to be the best investment, and this is the type now used on German main lines.

The author once initiated a study of the wear of straight track in Britain and the results now show[12] that corrosion effects play a great part. Various contents of carbon, manganese and chromium were included in the trials, and if one divides each of the last two elements by a factor of 3 or 4, and adds the result to the carbon content, a "carbon equivalent" is obtained. In the range examined, Dearden found that 10% reduction of wear follows for each 0·1% of equivalent carbon. Austenitic 12% manganese steel is well-known to give excellent service for busy crossings, and 0·5–1·0% chromium steel is also said[13] to show improved life in these positions. A trial by the author of chromium-nickel austenitic inserts (245 Brinell) welded from Armex 2 electrodes into the running surfaces of ordinary rails gave remarkable wear resistance, but this is not an economic solution at present. The development of continuous casting machines for rails may solve the problem in the future.

Copper bearing steels corrode less in the open air than plain steels, but this effect did not obtain in steam-traffic tunnels. No low-priced rail steel compositions are known which will effectively combat the corrosion factor.

Carriages and Wagons

Low-alloy steels having tensile strengths of 33–40 tons/sq. in. are of great interest in connection with rolling stock. Sections and weight can be reduced as compared with mild steel, but this advantage would only be worth while if increased corrosion resistance were also obtained. Additions of 0·6% chromium and 0·5% copper to material with 0·15–0·2% carbon give satisfactory results, and experiments on floor plates for coal wagons showed a saving of weight of 20% for equal service life. In passenger coaches and kitchen cars the 18/8 austenitic steel finds useful employment, and this must be of welding quality if welding is to be used in fabrication. The production of bogies of welded low alloy steels was at one time popular, but the incidence of fatigue cracks near the welds must be avoided by very careful design in these intricate assemblies.

Specifications

Since a large railway organisation uses considerable tonnages of steels, there is sometimes a tendency to introduce special specifications for material. This should be avoided as much as possible, as it leads to complications in the steelmaking plants. Furthermore, additional and intricate mechanical tests should be given deep consideration before they are introduced into specifications. The deleterious effect on costs and productivity of ill-considered specifications has recently been indicated,[14] and the effect could be considerable in the case of an organisation embarking upon a new programme for utilising alloy steels.

REFERENCES

1 Sully, A. "Manganese." London, 1955. Butterworths Scientific Publications.
2 Lemon, F., and O'Neill, H. *J. Iron and Steel Inst.*, 1942, **146**, 53–72.
3 O'Neill, H., Symposium on Fatigue, University of Melbourne, 1946.
4 Wilkinson, T. B., and O'Neill, H., *Proc. Inst. Mech. Engrs.*, 1939, **141**, 497–518
5 "The Metallurgy of a High Speed Locomotive," *Railway Gazette*, 1938, **68**, 303–311, 366–370.
6 O'Neill, H., *J. Iron and Steel Inst.*, 1937, **135**, 187–221.
7 O'Neill, H. *Proc. Inst. Civil Engrs.*, 1945. Railway Paper No. 15.
8 Waine, A. H., *J. Iron and Steel Inst.*, 1950, **165**, 279–286.
9 Ashdown, H. H., "*Metal Progress*," 1935, **27**, 29–42.
10 Bucknall, E., Nicholls, W., and Toft, L. "Symposium on Internal Stress." Institute of Metals Monograph and Report Series, No. 5. London, 1947, p. 351
11 "Ergebnisse der Erfahrung mit in den Geleisen der Gotthardlinie . . ." M. Ros and O. Wichser, Bauabteilung der Schweiz Bundesbahnen, Berne, 1952.
12 Dearden, J. *Proc. Inst. Civil Engrs.*, 1954, **3**, 456–505.
13 Swinden, T., and Johnson, J., *J. Iron and Steel Inst.*, 1928, **117**, 611–637.
14 O'Neill, H., *Metallurgia*, 1955, **51**, 121–124.

Modern Steel Foundry Plant on Show

K & L Open Day

The special fume-extraction cowling and exhaust pipes on one of the three 5/7 ton electric arc furnaces.

ON the inside front cover of the brochure issued by K & L Steelfounders and Engineers, Ltd., in connection with the recent Open Day, is a Ruskin quotation : " There is hardly anything in the world that some man cannot make a little worse and sell a little cheaper, and the people who consider price only are this man's lawful prey." The concluding quotation, on the inside back cover, is, with apologies to William Blake : "The dross of this world is beneath our attention." Between the two are some thirty extensively illustrated pages devoted to the facilities available for the production of the " quality controlled " castings on which the Company has established such a high reputation.

Since K & L were taken over by the George Cohen 600 Group in 1928, no money has been spared for modernisation, expansion and re-equipment. The possession of first class plant and equipment is not, however, any assurance of quality products—although it plays an important part, of course. In the belief that high quality is inevitably cheaper than low price in both the short and long run, K & L have consistently put quality before cost and price, and a high expenditure on research, control and inspection has produced standards of accuracy which are all too rare in this class of work.

The K & L steel foundries are among the largest in Britain, having capacity for well over 15,000 tons of castings a year. The site of the works at Letchworth occupies 70 acres, with half a million square feet of covered buildings. They comprise fully integrated Foundry and Engineering Divisions, with steel and bronze foundries, light and heavy machine shops and assembly bays. Ancillary departments include welding and fabricating shops, heat treatment shops, pattern shop, research and development laboratories and experimental and test shops.

The Engineering Division, while largely devoted to the manufacture of the Jones range of cranes, provides machining capacity for those customers who prefer to buy their castings in the semi-finished or finished machined condition. Of the total personnel of 1,700, the Engineering and Foundry Divisions employ roughly half each.

The Foundries

The Foundry Division serves a wide range of industries : it has a special interest in steam, electric and diesel-electric locomotive work, as well as important customers making earth-moving and mechanical handling equipment. A wide range of carbon, manganese, low alloy and high alloy steels is produced, suitable for general purposes and resistance to corrosion and heat. The Division caters for long production runs and medium batch production of castings up to 2 tons each in weight. A special section is devoted to heavier castings—up to 12 tons in weight. To keep in the forefront of the steel founding industry, the Company is constantly renewing its plant and installing much mechanical equipment. A new light foundry building was recently completed, giving an addition of some 70,000 sq. ft. of floor space to the Division. Most of the smaller repetition castings will be made in this extension, and the new plant will widen the range of alloy steels without interfering with the production programme of the existing basic electric arc melting furnaces.

The foundation for success in the production of a steel casting is laid at the design stage and, like all progressive foundries, K & L are willing—nay, anxious—to co-operate with the customer from the beginning, to ensure that the design requirements and the founding requirements are both met, as far as is possible.

Patternmaking

Once the design is established the production departments take over, and the first step is the making of the pattern. It has been truly said that a steel casting is only as good as the pattern from which it is made, and the up-to-date pattern shop is fully equipped to enable craftsmen pattern-makers to practise their skill to the best effect.

Prominent features of the shop are the teak wood block flooring, underdrawn roof, radiant panels, steam heated in the ceiling and the west wall, and full height glazing to the north and east walls. All woodworking machines have dust extraction running underneath the flooring to cyclone dust arrestors outside the building. A metal

A Wadkin routing machine being used in the making of a SCOA-P wheel centre pattern.

pattern section adjoins the pattern shop, and adjacent to it is one of the five large pattern stores, which together house approximately 9,000 patterns. An overhead sprinkler system covers the fire risk, and a duplicate set of pattern records is housed in fireproof vaults in the accounts department.

Sand Preparation

The sand mixtures used are chiefly synthetic sands bonded with Wyoming bentonites, using high silica sands as a base, and both the main foundry and the new light foundry are equipped with sand preparation and reconditioning plant. In the light foundry the sand from the shake-out passes by conveyor belt through a magnetic separator, to an elevator which transfers it to a hopper, with disc feed. Next it passes through a rotary screen to a sand cooling and desilting tower, thence by a further elevator and distribution belt to one of four 70 ton storage hoppers. New sand from a hopper is raised to the charge end of a rotary sand dryer and screen, from which it is raised to the top of the storage hoppers by a pneumatic elevator. The hoppers provide storage capacity for about 130 tons of new sand. Travelling weigh hoppers beneath the storage hoppers feed the correct amount of each type of sand to the sand mills and core sand mixers. This plant is capable of dealing with 20 tons per hour, and needs only two men to operate it.

A complete section of the laboratory is devoted to routine sand testing and research on new binders and refractory sands. It is equipped with the normal sand testing equipment for determining such properties as moisture, tensile strength and permeability, and samples are taken regularly from the sand mixing plants to ensure that each mix conforms to specification.

One of four Coleman Wallwork 800 lb. jolt squeeze pin lift machines in the new light foundry.

Moulding and Coremaking

The heavy foundry is equipped with jolt rollover machines and larger jolters for handling boxes up to 6 ft. square. Two 1,000 lb. Pneulec machines can handle 830 boxes (24 × 18 in.) per week with a time cycle of 3–5 min. Castings up to $2\frac{1}{4}$ cwt.* can be produced, and the weekly output is 20 tons. An 8-min. cycle on the two 2,000 lb. Pneulec machines, which can accommodate boxes up to 3 ft. square, gives an output of 700 boxes per week, yielding 53 tons of 3–6 cwt. castings. For the 4,000 lb. Pneulec jolt rollover the figures are: 110 boxes up to 4 ft. 6in. square, making up 19 tons per week of 10 cwt.—2 ton castings. There are two straight jar machines with crane turnover. The 5 ft. 6 in. model is used mainly on traction yokes, and it has been used for moulding a 5 ton casting. The weekly output of 35 tons obtained with the 5 ft. straight jar machine is made up of 115 boxes, up to 5 ft. square, in which a maximum weight of up to $3\frac{1}{2}$ tons can be cast. There is also a hand moulding section where castings up to 12 tons can be moulded, although they do not generally exceed 8–9 tons. A sand-slinger is used to save ramming the backing sand by hand, and the weekly output is of the order of 25 tons. Green, skin dried and dried moulds are used, and the foundry is equipped with three coke fired drying stoves.

For the quantity production of small intricate castings having thinner-than-average sections, the shell moulding process is used.

Smaller sections are fully mechanised, in the light foundry, having jolt squeeze pin lift machines for

* As-cast weights (including heads, etc.) given in each case.

producing copes and drags. Castings up to 50 lb. in weight are moulded in 18 × 12 in. boxes on a 300 lb. Coleman Wallwork jolt squeeze machine, which can handle 150 boxes per week with an output of about a ton. The four 800 lb. jolt squeeze pin lift machines work in pairs with a 3–5 min. cycle. From the 440 24 × 24 in. boxes handled by one pair there is an output of 16 tons per week, and the same production is obtained from the other pair, on which 750 24 × 18 in. boxes are moulded each week. The castings produced from these moulds weigh up to 2¼ cwt. as-cast. The largest machines in this foundry—two 1,400 lb. jolt squeeze rollover machines—handle 450 24 × 24 in. boxes a week with an output of 16 tons. The castings weigh up to 3 cwt., and the cycle of operations is about 6 min.

The light foundry also accommodates the shell moulding plant, which is, of course, used for the quantity production of small intricate castings, having thinner- than-average sections. By this method, closer dimensional (and weight) tolerances are possible, and machining can be eliminated or greatly reduced. The output of this section is about 1 ton per week.

Large cores are hand made by skilled craftsmen, and a mechanised core shop produces 150,000 cores per week. Oil sand is fed by hopper to each operator, and blowing machines and other mechanical aids are widely used. The moulded cores are placed on a continuous moving conveyor belt feeding into the drying stoves, which operate at 350–400° F. and a cycle of 90 minutes. Batch type stoves are provided for drying the large cores. After baking, the cores are checked, jointed if necessary, and painted.

Melting and Pouring

The heavy foundry melting shop covers an area of 12,000 sq. ft., and houses two 5–7 ton basic-lined Birlec electric arc furnaces of the swing-roof type. Refining by oxygen injection, in which K & L were one of the pioneers, is carried out as routine practice. Each of these two furnaces has a power input of 3,500 kVA. and a production rate of 2 tons of refined steel per hour. They work continuously from 6 a.m. Monday to noon on Saturday, and have a weekly output of 200–250 tons each. The power consumption per ton is 650 kWh. and the electrode consumption 12·5 lb. per ton. The electrode feed is automatically controlled by an amplidyne system, and temperature measurement is effected by means of platinum/platinum-rhodium thermocouples.

A similar 5–7 ton arc furnace is installed in the light foundry, but this unit is only operated from 7.30 a.m. to 5 p.m. daily. The output is of the order of 70 tons per week, and the power consumption and electrode consumption per ton are up, at 750 kWh. and 18 lb., respectively. The lining life is increased to twelve weeks, but the roof life remains at three weeks.

The light foundry also houses a 600 kW. high frquency melting installation. Current at a frequency of 1,000 c./s. is provided by an alternator set driven by a 1,000 h.p. motor operating direct from the 11,000 volt supply. The installation includes two 25 cwt. bodies and one 5 cwt. body, which may be acid or basic lined, the lining life being about a week. The output of this installation is 40 tons per 44 hour week.

The 600 kW high-frequency melting installation.

The three electric arc furnaces have a cycle time of 2½ hours for each melt. Tapping is effected by controlled tipping into ladles suspended from overhead cranes. The furnaces have a high angle of tilt—up to 45° by limit switch and up to 50° manually. The melting rate for the high frequency furnaces is such that a full charge of 25 cwt. can be melted in about 80 minutes.

After tapping, the steel is taken to the appropriate section by power-driven bogies, transferred to one of the overhead cranes and poured. To ensure good surface finish and high soundness, K & L are constantly improving gating practice and heading technique. They were one of the first companies to apply exothermic powder additions to promote more efficient feeding.

Ingot Production

Besides steel castings, the Company casts ingots to forging and aircraft specifications. They are all fully killed and are bottom poured, feeder heads being used to promote soundness. The standard sizes are 11½ cwt.,

Pouring a casting : note the bags of exothermic powder for adding to the feeder heads.

One of the several batteries of automatic temperature controlled heat treatment furnaces.

33 cwt., 54 cwt., 106 cwt., and 116 cwt., and the output of this class of material may be as much as 100 tons per week. After casting, the ingots are transferred to the soaking pits, where they remain for about three days, depending on the carbon content.

Dressing

Shot blasting is carried out in five cabins, working on air pressure of approximately 90 lb./sq. in., and in special Wheelabrator plants. Medium and small castings are shot blasted by two special Tablast plants—the first of their kind to be used in this country. In the light foundry, there is a continuous shot blast plant. It consists of a pendulum/chain conveyor carrying a series of hooks which follow a U-shaped course, passing 4 impeller-type blasting wheels. A casting is unhooked from the conveyor each minute, and each hook can take up to 10 cwt., depending on shape. The normal processes of burning-off, grinding and dressing are carried on in the light, medium and heavy fettling bays. Where

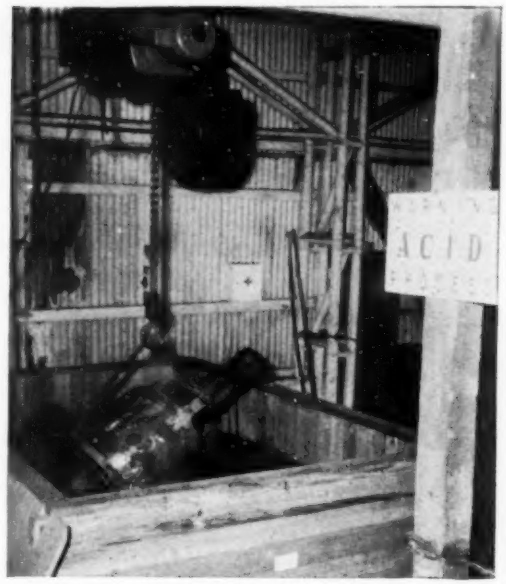
A gamma-ray cubicle using 3 Curie Cobalt 60 source to obtain routine radiographs on a miscellaneous collection of steel castings.

necessary, slight distortion can be rectified in a straightening press.

Heat Treatment and Machining

Normalising, hardening and tempering are carried out in six 170–240 kW. Birlec electric heat treatment furnaces, and for the batch heat treatment of small castings, such as track links, needing liquid quenching, there are two 80 kW. rotary hearth furnaces. Three 60 kW. Birlec R.P.60 batch type furnaces are in use for general heat treatment up to 1,100° C., and annealing is also carried out in Buell oil-fired temperature controlled furnaces.

A British Oxygen flame hardening machine is used for surface hardening gear teeth and for general surface hardening operations : gear teeth are usually hardened to a depth of $\frac{1}{16}$ in. There is also a 35 kVA. Efco induction



Acid pickling for the detection of surface flaws.

hardening installation used for, among other things, the surface hardening of track link pins.

Machining facilities are available to handle nearly every size and type of casting made by the foundry, and some 30% of the output is delivered in the machined or partially machined condition. K & L's machining capacity comprises over 400 modern machine tools, including lathes, vertical borers and milling machines—some of special purpose design—the average age of which is under nine years.

Inspection and Testing

For the purpose of ensuring the quality of all castings leaving the works, a comprehensive system of inspection and testing has been developed. All K & L standard steels are made to British Standard Specifications and their specified properties are in constant check. Lamson pneumatic tubes connect the laboratories with the melting shops to provide for a rapid analysis of all the principal elements, so that the resident steel plant

metallurgist can have a final check before tapping takes place. Every heat of steel is analysed, using chemical and physico-chemical procedures. Mechanical tests are also carried out, the equipment including a Hounsfield Tensometer, a Denison tensile and bend testing machine, an Avery Izod impact testing machine, and a Brinell hardness testing machine. Magnetic permeability tests are also carried out on castings for electrical machines.

In addition to these material checks, inspectors are stationed in the pattern, moulding, coremaking and fettling shops, to ensure dimensional accuracy and soundness. Further support on the latter point is given by non-destructive testing. By special arrangement with the customer, castings subject to pressure or other forms of high duty can be submitted to systematic radiographic inspection. The K & L laboratories are equipped with five sources of X- and gamma-rays, which are used mainly for the improvement of feeding and running techniques. No production run of any size is commenced before sample castings have undergone radiographic examination. In addition to radiography, magnetic crack detection and acid pickling are routine inspection procedures.

The company produces a wide range of castings for a variety of interests, including high pressure valve bodies for steam, water, oil and air systems, gear blanks, electric motor castings, high alloy steel castings, and the SCOA-P patented locomotive wheel centre castings, for the manufacture of which K & L is the only licensed foundry in this country.

Kinetic Heating in Aircraft and Guided Missile Structures

Metropolitan-Vickers System for Laboratory Simulation

DURING the high-speed flight of modern aircraft and guided missiles, the temperature distribution in the structure becomes a feature of vital interest to the designers. It is essential to simulate in the laboratory the conditions likely to be met during high-speed flight, and to study the deformations caused by the thermal stress where unequal temperature distributions are caused due to changes in speed. Metropolitan-Vickers Electrical Co., Ltd., has for the past twelve months been developing a complete system for this purpose, and the necessary equipment is now available to aircraft manufacturers.

The power requirement for the simulation of kinetic heating varies with the size and designed operating conditions of the specimen under test, from tens of kilowatts in pilot schemes to tens of megawatts where a full-sized project is on test. In the M-V system, provision has been made to supply either controlled A.C. or controlled D.C. to meet this need; controlled D.C. systems are generally favoured, because of interference problems on the large numbers of measuring instruments. The power controllers may be either static (flux-resetting magnetic amplifiers or mercury arc rectifiers) or dynamic (field-controlled D.C. generators or servo-controlled A.C. regulators), all being available in types having the required response.

A block schematic diagram of the whole simulation system is given in Fig. 1. It will be seen that the control system for heating and stressing comprises a "Metrovick 950" digital computer, a function generator, and loading and heating controllers. The computer (1) is used to produce the parameter programme on which the tests are to be conducted. Its output can be on five-hole punched paper tape, which is then fed into the function generator (2).

The simplified equation for heat flow into the structure gives:

$$\frac{Q}{A} = h\,(T_{aw} - t_s)$$

where $\frac{Q}{A}$ = computed heat per unit area (required).

h = heat transfer co-efficient.

T_{aw} = adiabatic wall temperature.

and t_s = specimen surface temperature.

The function generator has been designed with a view to the addition of further terms in cases where a more rigorous solution is required. It has also been arranged to provide, where required, a programmed control of forces applied to the structure during the test in synchronism with the heating cycle. The heating and loading programmes can be produced either by a single function generator or, where the time scales differ, by separate function generators. Systems can also be arranged to control the surface temperature t_s instead of the heat flow Q, if so desired.

In Fig. 1, the outputs of the function generator are taken to the several heating and loading controllers, but for simplicity only one heating controller (3) and one loading controller (7) are shown. The output of the heating controller (3) is taken to a bank of infra-red lamps (4), which are suitably located with respect to the

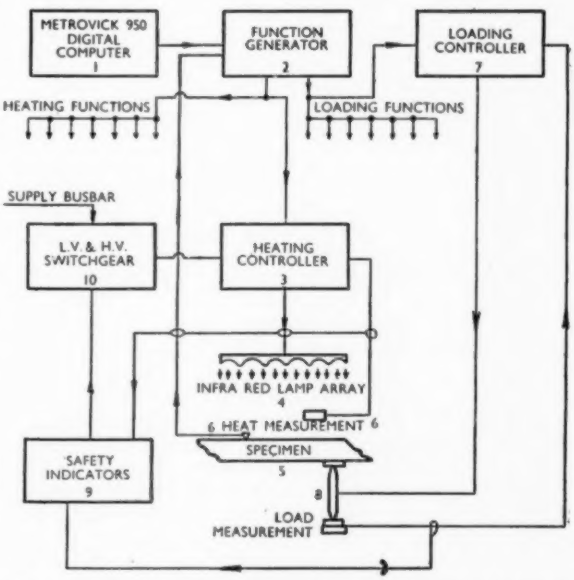


Fig. 1.—Block schematic diagram of complete kinetic heating simulation system.

structure specimen (5). The heat measurement device (6) feeds back signals to the function generator and heat controller to maintain the desired heating function. Similarly, the output of the loading controller (7) is taken to the load actuator and load measuring device (8), which applies the required force to the structure and provides a signal that is fed back to the load controller.

For protection in the event of structural or system failure, circuits are included which can be arranged to shut down the heating and loading systems with minimum delay. H.V. and L.V. switchgear (10) can also be supplied to suit the user's requirements.

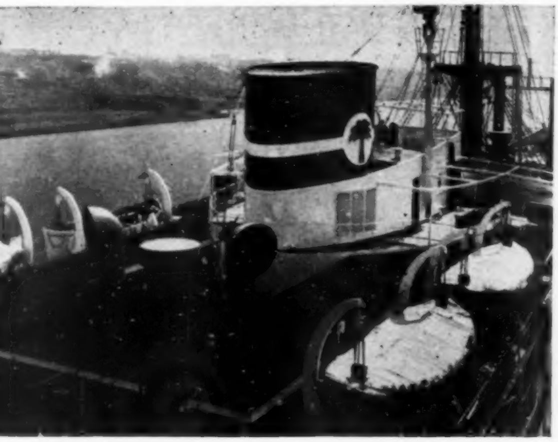
The objective of this new Metropolitan-Vickers development has been to provide a co-ordinated system for kinetic heating tests, while retaining the flexibility necessary to meet the varying requirements of different users. All the equipment from the H.V. switchgear and transformers to the infra-red lamps with their reflectors and supporting structures can be supplied by the M-V Company, thus relieving the user's staff of the work of designing their own gear or co-ordinating the specifications of individual items obtained from different suppliers.

Cargo Ship with Aluminium Deckhouse Structure

An interesting example of unusually extensive use of aluminium in a cargo vessel is the M.S. *Elmina Palm*, an open shelter deck ship of 425 ft. B.P., 8,088 tons d.w., recently completed for the Palm Line by Swan, Hunter and Wigham Richardson, Ltd., of Neptune Works, Newcastle upon Tyne. In the service for which the *Elmina Palm* is designed, she must operate up West African rivers with a severe draught restriction at the mouth, and to obtain the maximum possible deadweight in these conditions, as well as to improve the deadweight generally, much use has been made of aluminium in the midship deckhouse structure and for fittings and equipment.

There are four tiers of midship deckhouses, and although the lowest of these is in steel the whole of the structure above the bridge deck is of aluminium (apart from the engine casing). The deckhouses are almost entirely welded, and form in fact the first welded aluminium structure of any extent aboard a British built and registered ship. By careful design it has been possible to replace a steel weight of 87 tons in the deckhouse and funnel with 32 tons of aluminium, which represents a weight saving of 63%. This favourable weight ratio is partly due to the use throughout the structure of the special aluminium bulb sections standardised in B.S.2614 : 1955 "Aluminium Alloy Sections for Marine Purposes." The connections between the aluminium and the adjacent steel structures were made with steel rivets, and a gasket of Neoprene rubber was fitted between the faying surfaces. Special consideration was given to fire protection arrangements for the aluminium structure, and ⅜ in. of sprayed limpet asbestos was applied to the house side and the deck in the vicinity of the boat stations and the supporting structure, and to the deck under the radio room.

Other aluminium applications, besides fittings directly connected with the structure, include permanent awnings, hatch boards, heating coils, accommodation ladders and lifeboats, of which the awnings and hatch boards are of especial interest. The awnings, which replace conventional teak awnings, are of 20 s.w.g. Noral Industrial sheet, supported by a complete framework of aluminium bulb angle sections. Industrial sheet is of a profile that enables it to be used in this comparatively thin gauge and yet to provide sufficient strength to be walked on freely. Aluminium hatch boards are fitted for trial purposes on the hatch on the forecastle deck, and were supplied by Fairmile Construction Co. to a design prepared by Northern Aluminium Co., Ltd. The boards are of ¼ in. aluminium sheet formed into a box section, and satisfy the requirements of Lloyd's Register and the Ministry of Transport for weather deck hatches. Alacoil aluminium heating coils, supplied by Steel Engineering Installations, Ltd., of Sunderland, were fitted in Nos. 3 and 4 double bottom tanks.



In this view can be seen the aluminium lifeboats, permanent awning, funnel, and part of the extensive welded aluminium deckhouse structure.

The total saving in weight due to the aluminium structure and fittings (which include lifeboats) is about 74 tons, resulting in a corresponding increase in deadweight over a similar ship of normal construction. All the aluminium used in the structure was supplied by Northern Aluminium Co., Ltd.

Aluminium Films List

In the new edition of the Aluminium Development Association's list of films, film strips and wall charts, 16 mm. sound films (numbering nearly fifty) now available on loan have been classified under the general subjects of: production, working operations, joining and applications. They include the film recently produced by the A.D.A., in conjunction with the manufacturers and users concerned, of unpainted aluminium subway cars designed and constructed in Great Britain for service in Toronto, Canada. The book also gives details of 35 mm. film strips available on loan, and of educational wall charts.

Grab Dredging for Minerals in the Open Sea

THERE has just been completed the first of a new type of tin dredge which will be employed on tin-bearing properties in the open sea off the West Coast of Siam where the owners, Aokam Tin, Ltd., have extensive properties.

This dredge, the *Pibul*, was originally built as an oil tanker and as this particular design lent itself to the layout of a grab tin dredge it was purchased for this purpose. The conversion work, which, consisted of the removal of some 450 tons of machinery and steelwork from the original hull, was carried out under the supervision of the consultants, Priestman Brothers, Ltd., working in co-operation with the chief engineer to Aokam Tin, Ltd., the work being carried out on the Prai River, Nr. Butterworth, Province Wellesley, Malaya.

The work, which took approximately two years to complete, has resulted in the vessel being completely changed in appearance, as will be seen from the illustration.

The original diesel-driven twin-screw machinery was removed and in its place were fitted three diesel alternators to provide power throughout the vessel for all purposes. In the same compartment twin-screw A.C. electric propulsion motors are fitted, together with the associated distribution boards, control gear, resistance units and other auxiliary equipment.

The two Priestman 4 yd. deep grabbers were fitted forward on a specially constructed false deck structure which overhung the sides of the vessel as shown on the illustration. These two dredging units, which are of the level luffing type, each handle a 4 cu. yd. Priestman heavyweight grab of the four-rope type at depths down to 220 ft. below water level. The total load of grab and contents is 15 tons and the hoisting speed 400 ft./min. The maximum outreach is 40 ft. and the minimum for discharging purposes is 20 ft.

The winch mechanism for each dredging unit consists of a Ward Leonard motor generator set controlling two hoisting and holding motors which drive the winch mechanism. With the Ward Leonard control system complete speed control can be obtained. The operators of the two units are stationed in the pilot house, one at each side of the vessel, and through the side windows they have a full view of their work and are able to control the units with the minimum of effort and the maximum efficiency. At 100 ft. depth below water level it is anticipated that the output per dredging unit will be in the region of 200 cu. yd./hr.

Once the material has left the grab it passes through grizzley bars into feed hoppers, from which it is removed by means of a plate type feeder, one of which is placed at each side of the vessel and which deliver the material on to a central elevating conveyor to raise it into the mouth of the revolving screen. From the revolving screen the material is discharged into a specially designed distribution box which leads it into the jigs placed on either side of the vessel. After a final cleaning up and washing process the tin ore is bagged on board the vessel and stored in a special compartment.

The total installed h.p. on board the dredge is 3,200, and the total weight of machinery and structural steelwork which was added in order to convert the dredge was approximately 1,100 tons.

B.S.C.R.A.-S.F.S.A. Exchange Lectures

THE British Steel Castings Research Association announces that it has entered into an arrangement with the Steel Founders' Society of America for the exchange of information at their respective annual conferences. Each association will, in alternate years, invite the other to nominate a speaker to address its annual conference on a selected subject. The scheme is being initiated this year with an invitation from the S.F.S.A. for representatives of the B.S.C.R.A. to address the S.F.S.A. Technical and Operating Conference in Cleveland, Ohio, November 11th to 13th, on the subject of the application of the graphite-rod resistor furnace to steel foundry practice, and the use in steel foundries of the immersion pyrometer for the measurement of liquid steel temperatures.

The B.S.C.R.A. has nominated MR. T. A. COSH, head of its steelmaking section, and MR. L. W. SANDERS, chief metallurgist, Lake & Elliot Ltd., to present this paper, their two organisations being the first in this country with experience of the graphite-rod resistor furnace for the production of steel. Mr. Cosh and Mr. Sanders expect to leave for the United States at the end of October, and to include visits to a number of steel foundries and metallurgical research organisations in their itinerary.

Improved Control for Forging Presses

FASTER and more accurage forging is possible with the system of position control devised by the British Iron and Steel Research Association's Plant Engineering Division* and installed on the 200-ton press in the Association's Sheffield Laboratories. With a conventional control system the press operator has to judge the right moment to stop the crosshead; this is because he controls the *velocity* of the crosshead. Expressed in mathematical terms, what he does is to integrate the velocity with respect to time. With position control, this integrating function is performed for him, and the crosshead is automatically brought to a stop at the right place. Position control thus demands less skill of the operator, and at the same time reduces the possibility of human error.

The principle of the method is quite simple. It depends on comparing voltages from two potential dividers, one at the control desk, the other attached to the press. The first voltage depends on the position of the operator's control; the second depends on the position of the press crosshead. The difference between these two voltages is amplified and used to operate the valves of the ram of the press. When the two voltages become equal, the valves are closed and the ram comes to a standstill. A necessary refinement is the provision of additional feedback to prevent the crosshead overshooting and hunting up and down before coming to rest. The entire arrangement is shown in the diagram.

The control desk of the press in the Sheffield Laboratories has two dials and three levers. The two dials are for setting the upper and lower limits of the crosshead stroke. One of the three levers is for changing from manual to position control. Each time the second lever is operated the crosshead will move up or down to one of the selected positions set on the two dials. The third lever is for automatic repetitive stroking. The crosshead continues to move up and down as long as this lever is set.

The installation on the press at Sheffield by no means represents the fullest development of position control; it was intended primarily to establish the feasibility of the method. Nevertheless, 3-in. bars have been forged to tolerances of $\pm \frac{1}{64}$ in. and tool marks between successive strokes were absent. Moreover, this improved equipment, installed at low cost, has been in use for several months without any electrical failure having occurred.

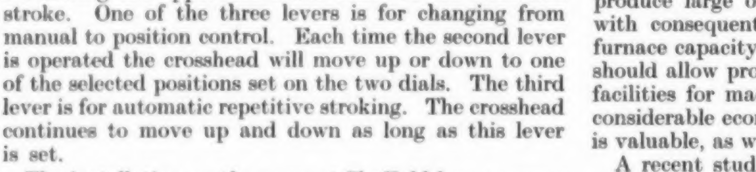
* British Patent Application No. 33230/56

Visitors to B.I.S.R.A.'s Sheffield laboratories watching a demonstration of position control on the forging press.

On production presses, the increased rate of forging given by position control should make it possible to produce large or complicated forgings in fewer heats, with consequent improvements in productivity where furnace capacity is inadequate. The increased accuracy should allow production to be increased in forges where facilities for machining limit output, and should bring considerable economies where the material machined off is valuable, as with high-alloy steel forgings.

A recent study of a roll-forging operation with conventional control revealed that no less than a quarter of the time spent in forging might have been saved if the press had been equipped with position control. B.I.S.R.A. intends to apply the method to manipulating equipment as soon as possible.

Among further advances that can be expected to follow position control of forging is the use of the translator, also developed by B.I.S.R.A. for marshalling all input information and obtaining automatically a suitable forging programme. Alternatively, programmes may be stored on punched cards or tape.



R – INPUT UNIT CONVERTS DESIRED POSITION INTO A VOLTAGE
S – OUTPUT POSITION UNIT CONVERTS ACTUAL POSITION INTO A VOLTAGE

Block schematic diagram of B.I.S.R.A. position control system.

Fulmer Research Institute

A Decade of Sponsored Research

WHEN it was founded in 1946, the Fulmer Research Institute symbolised a new development in this country—sponsored research on a commercial basis. The aim was to provide a scientific and technical service for the industrial community, and Sir Stafford Cripps, when opening the laboratories on July 2nd, 1947, said that the Institute would help to fill a gap in the organisation of research in the United Kingdom. It could provide all or part of the research effort for those firms lacking adequate private facilities or staff, in a way not catered for by the government research institutions, research associations or university laboratories.

The tenth anniversary of the official opening—which was marked by an Open Day on July 2nd, 1957—provides an opportunity to review progress since the Institute's inception. During this period the staff has increased from 44 to 107 and the annual research income has risen from £25,000 to £125,000. This growth reflects the continued and expanding demand for the Institute's services, from both old and new sponsors. Investment in new buildings and equipment has been doubled, largely as a result of the parent company, Almin, Ltd., ploughing back all the profits.

Although the Institute was founded as a service to British industry, and sponsorship from this source has grown steadily throughout this period, particularly in the field of testing, analysis, and short-term investigations, industrial sponsors from the United Kingdom represent only about 25% of the total. About half the Institute's work is for government departments and nationally owned undertakings. The Institute receives no direct grants from public funds, however, its income from government agencies being on the basis of payment for work done under contract. Government sponsorship of certain major research projects has resulted in the development of highly skilled research teams to the ultimate benefit of industry when they are deployed on the investigation of similar problems directly for industry. Mention must also be made of the increasing dollar income which the Institute derives from both American industry and U.S. government agencies, particularly the research and development branches of the armed forces. The present annual value of dollar contracts exceeds $120,000.

Under the normal conditions of sponsorship, investigational work is carried out on a strictly confidential basis, with the results (including patents) belonging entirely to the individual sponsor. Thus the Institute is basically a laboratory for hire, and can be viewed as a simple extension of the private facilities of a company. The advantages of using a research service of this kind are many. Trained staff and costly equipment, which could not be maintained privately except by the largest industrial concerns, are made generally available to industry, together with the benefits of special skills which the staff may have acquired. Investigation of important problems which, due to pressure of other essential work, might be seriously delayed, can be conveniently delegated to the sponsored research laboratory, with the knowledge that commercial benefits will still be secured by the sponsor. A similar consideration applies to those longer term problems which are continually interrupted by the need for special effort on production problems. A completely fresh approach to a problem frequently results in new ideas and rapid progress and, in addition, the close contact of scientists of widely differing experience and training is of considerable value in this respect. Despite the national shortage of scientific personnel, staff recruitment has not been a major problem, and it has been possible consistently to maintain a first-class team of highly qualified investigators, which is believed to be due to the opportunities and interest offered by the problems under investigation.

Most of the work of the Institute has been of a metallurgical or chemical character, but problems relating to glass, ceramics, plastics, textiles, timber and asbestos, which have come within the orbit of training and experience of the widely qualified staff have been undertaken. Developments in atomic energy have been reflected in the increased amount of work on uranium and on other metals which are of possible interest in this field. Titanium, zirconium, vanadium, niobium and hafnium all figure prominently in the current programme. Work on aluminium and its alloys, although giving way to that on the "newer" metals, is still of outstanding importance.

Specialised Equipment Available

Metallography.

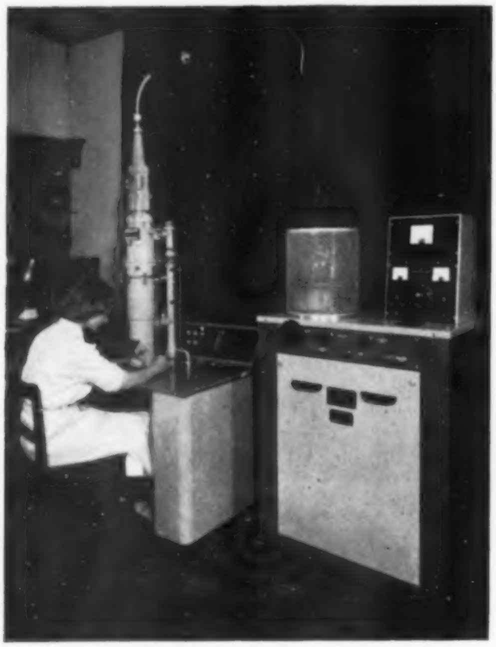
In addition to the Bausch and Lomb Metallograph and the Reichert projection microscope, there are several bench microscopes, including a Beck bench binocular microscope, and a Beck bench microscope which can be used for phase contrast studies or microhardness testing (using a G.K.N. hardness tester). For low power work there are a Watson binocular microscope and a Beck vertical macro camera. Considerable experience has been built up in the metallography of uranium and its alloys. An instantaneous specific heat apparatus is available for equilibrium diagram work, and special apparatus has been designed to give ultra-rapid quenching from vacuum or special atmosphere heat treatment.

Electron Microscopy.

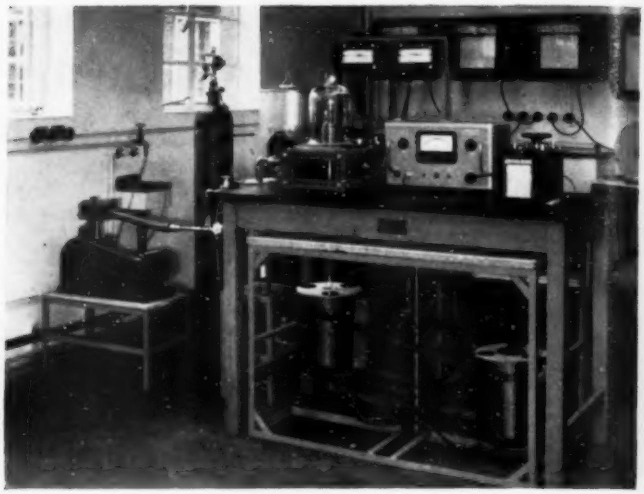
A Metropolitan-Vickers EM3A electron microscope, together with ancillary equipment in the form of an evaporation unit for replica preparation, is available, and has proved useful, for example, in an investigation of the character of the oxide film formed on alloys, in a study of phase transformations, and in the examination of asbestos fibres, contaminated catalysts, and magnetic powders

X-Ray Crystallography.

Five X-ray generators are in current use, and all the normal techniques of X-ray crystallography are available. Special techniques involving the use of mono-



Electron microscope and vacuum coating unit.



Dilatometer used for coefficient of expansion and isothermal transformation studies. Air heating furnace and lead quenching bath beneath table can be rotated into position for use.

chromatic radiation have proved particularly useful in the study of age-hardening and similar phenomena. Some work has also been carried out using a reciprocal lattice camera. In addition to the normal high temperature camera, a special camera has been developed to enable X-ray studies to be made of highly reactive materials at temperatures up to 1,000° C. This camera, which is of novel design, has proved vital in the examination of titanium and zirconium alloys. It can operate at temperature with a vacuum of 1×10^{-7} mm. of mercury. The study of the structure of liquid metals is made with a specially designed camera and a Geiger counter spectrometer.

Vacuum Melting and Casting.

Apart from the normal oil and gas fired furnaces for melting, induction furnaces have been adapted for melting and casting in special atmospheres, or in vacuo, and for zone refining, as well as for open melting. For highly reactive metals there are the vacuum arc melting furnaces in which small chill castings can be made, using water-cooled copper moulds. One of these is equipped with a retractable hearth, from which small billets suitable for extrusion can be made.

Refractory Preparation.

Special techniques for the preparation of refractories for dealing with highly reactive metals have been developed. A kiln is available for firing refractories at temperatures up to 2,000° C. Ball and roller mills allow for the preparation of finely divided material for slip casting or spraying. A diamond cut-off wheel provides for accurate shaping and cutting of thin slices of hard brittle substances.

Metal Working.

For working and shaping metals a forging hammer and small rolling mill are available, the latter being suitable for the production of either rod or sheet. There is also a 60-ton press for use with powder metallurgical techniques and a miniature extrusion plant. Arrangements have been made outside the laboratories for the extrusion of highly reactive and refractory materials, some of which have been sheathed and extruded using glass lubrication. This technique has proved particularly valuable in the investigation of chromium and chromium-base alloys.

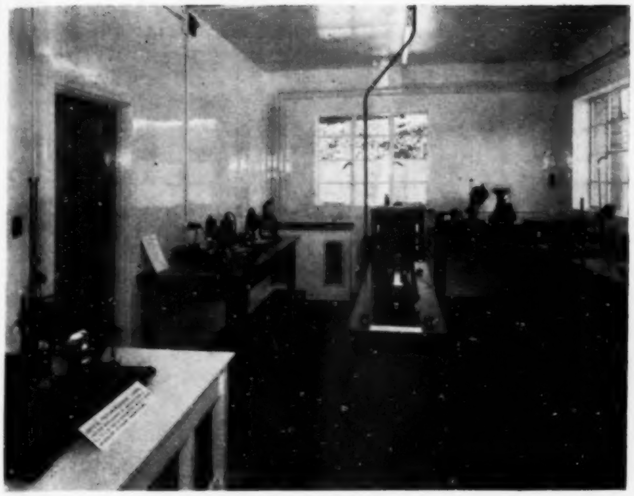
Mechanical Testing.

The usual mechanical tests can be carried out at either very low or high temperatures, and data have been produced for sponsors interested in designing for low temperature applications such as the transport of liquid methane. For high temperature design data, both fatigue and creep testing equipment are in use. Replica techniques are being used to study the progress of fatigue cracks, and a specially designed high temperature fatigue machine for testing sheet has proved particularly useful in studying the effect of various heat-resisting coatings on the high temperature fatigue properties of the basis metal. High temperature and corrosion fatigue studies are also being made using alternating tension and compression machines of the Haigh or "slipping clutch" type.

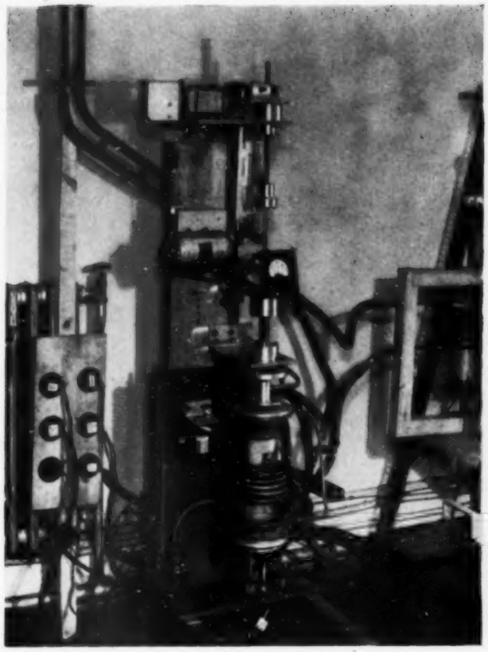
Conventional creep testing apparatus is supplemented by facilities for carrying out creep in compression, and in special protective atmospheres. This has proved essential in studies of the compression creep of uranium and other highly reactive metals. Both static and dynamic strain gauge measurements have been made under load. This work has been done in the field as well as in the laboratory.

Physical Chemistry.

Specialised techniques in the field of physical chemistry include accurate measurement of vapour and reaction pressure, using the capillary vessel method developed in the Institute, in addition to all standard methods. These have been used to study the equilibria of important industrial reactions and to establish activity data for various metallic systems. Accurate calorimetry has established the heats of formation of various compounds,



General view of microscope room showing : left—vertical macro camera and bench microscopes ; centre—metallograph ; right—low power binocular microscope and universal camera microscope.



Apparatus for drawing silicon single crystals.

in particular metallic halides, and new values for the heats of formation of several of these important compounds have been established and published. The kinetics and equilibria of various reactions that might form the basis of new extractive methods have been studied in apparatus requiring highly efficient vacuum techniques.

Corrosion Testing.

Accelerated laboratory and field tests at industrial, marine, and rural sites are used to assess corrosion behaviour. Salt spray cabinets and various types of stress corrosion apparatus are available. Current programmes are concerned, for example, with evaluating protective finishing schemes for structural steels, and with examining the corrosion and stress corrosion behaviour of the high strength aluminium alloys. Apparatus simulating a domestic water installation has been designed and used to determine the corrosion resistance of, and water contamination caused by, a potential new alloy for domestic boilers. Studies are being made of the oxidation of metals, including zirconium, at high temperatures.

Electrodeposition.

Four separate rectifiers deliver direct current supplies up to 250 A. at 60 V., enabling experimental electrodeposition to be carried out on a scale ranging from beakers to full pilot plant. These facilities have been used extensively for the preparation of pure chromium, and work has been carried out on the electrodeposition of manganese, and on the anodising and dyeing of aluminium and its alloys.

Chemical Analysis.

Conventional polarographic, absorptiometric, microchemical and, particularly, spectrographic methods have been used for the solution of a wide variety of difficult problems. The co-ordinated effort in using a combination of appropriate techniques has enabled new methods to be developed for one analysis, and for trace elements in phosphors, pharmaceutical products, graphite, etc.

Scope of the Work

Although it is impossible in the space available to refer to more than a few of the investigations and researches undertaken by the Institute, the following notes on work completed or in progress will provide an indication of the fields in which work has been undertaken. In some cases only a brief outline of the work is given, owing to the confidential nature of the problems.

Extractive Metallurgy.

The development by Dr. Gross in the Institute laboratories of a process for the catalytic distillation of aluminium is already well known. This process depends on the reversible reaction between aluminium trichloride and an aluminium-bearing material to form a volatile monochloride, which subsequently decomposes into aluminium and aluminium trichloride. The reaction is applicable to the extraction of aluminium from alloys produced by direct thermal reduction of bauxite or other suitable aluminium-bearing minerals in an arc furnace, or to the purification of scrap. Aluminium of high purity has been produced by this method. Extensive development work is being carried out on a pilot plant scale, and supplementary laboratory work is continuing at the Institute.

This method of approach to problems in extractive metallurgy has been followed by the study of related methods for the preparation of titanium, and a new process of titanium extraction, which has been covered by patents, has been developed on a laboratory scale, and is ready for extension to the pilot plant stage. Another related method is suitable for the purification of some other metals. Promising results have been obtained for beryllium.

Atomic Energy.

Various investigations connected with atomic energy are in progress, some concerned with the physical

View of the creep laboratory, showing: foreground—two B.N.F. 2 ton tensile machines; left background—a battery of B.N.F. 1 ton tensile machines; and right—five Denison 5 ton high accuracy tensile machines.

metallurgy of uranium and its alloys, and the study of liquid metals. Imported work is also in hand on the measurement of thermodynamic activities in various binary uranium systems. High temperature creep studies are being made of low alloy steels to provide data for designers of nuclear power plant, and creep tests are being carried out in compression and in special atmospheres on uranium and its alloys. A brief survey of packaged reactors for isolated site operation has also been made.

Precipitation Hardening.

A study of the mechanism of precipitation hardening, with particular reference to light alloys, has always been a major item in the Institute's research programme, and the X-ray techniques developed by the Institute's investigators for studying precipitation processes are well-known internationally to specialists in the field. Trace elements have been shown to exercise a profound effect on ageing behaviour in some systems, and the influence of small quantities of cadmium in accelerating the ageing of aluminium-copper alloys has resulted in the development of the aluminium-copper-cadmium alloys, which, while free from room temperature ageing after solution treatment, can be aged at elevated temperatures to give properties approaching those of the duralumin-type alloys. More recently, the effects of radiation on precipitation and ageing behaviour have been shown to be important.

Chromium and its Alloys.

Following a comprehensive investigation of the properties of certain binary and ternary chromium-base alloys, recent work has concentrated on high purity metal. Experimental and pilot plant work on electrolytic processes has been concerned with identifying and controlling commonly occurring impurities, and this has been coupled with an examination of the effects of these impurities on mechanical properties. Appreciable ductility has been achieved at room temperature in pure chromium, using metal produced in the laboratory by electrodeposition, and work is continuing on alloys.

Ferrous Metallurgy.

In addition to the investigations on the creep and fatigue properties of protected low alloy steels, research and development work on oxidation-resistant alloys is in progress. Low alloy silicon-aluminium steels have been developed which, in air in the temperature range 600–950° C., exhibit oxidation rates comparable with 18/8 stainless steel. These steels are expected to find application in heat exchangers, electric furnaces, etc. Further metallographic work on the causes of failure of high speed steel tools has also been carried out. Work has also been done on nodular cast iron.

Aluminium, Titanium and Silicon.

Apart from the age-hardening studies, work on new aluminium alloys includes the development of an aluminium-tin bearing alloy and of a structural alloy with improved corrosion resistance. The mechanism of layer corrosion and of stress corrosion in structural aluminium alloys is being studied. Attention is also being paid to anodic finishes, including an examination of the light-fastness of dyed anodic sections, and to the development of a method of protecting light alloy forgings and extrusions. Investigations on titanium include a study of the effects of hydrogen, and of the formation and nature of the embrittling *omega*-phase in binary titanium alloys. Experimental work on the purification of silicon is in progress, and techniques for the production of large single crystals from super-pure silicon and the manufacture of devices therefrom are also being developed.

Ancillary Services

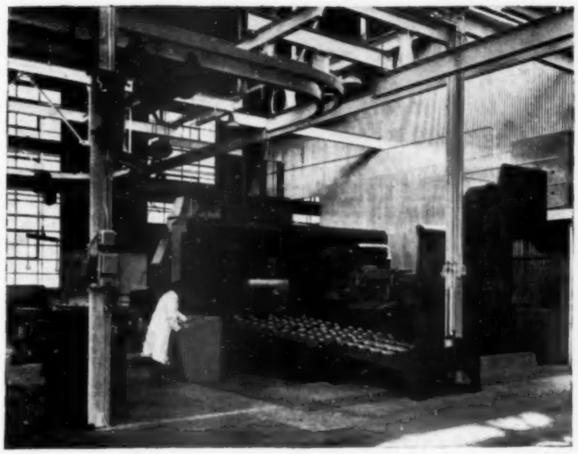
While relatively long-term research work accounts for the major proportion of the Institute's activities, facilities exist for testing and analysis, for investigation of routine difficulties, and for related work of short duration; the Institute is A.I.D. approved for both mechanical testing and chemical analysis. Over 1,700 short-term investigations have been completed. These have included the examination of service failures in a wide variety of materials and manufactured products, such as television aerials, dental and surgical equipment, gear cutters, automobile engine parts, addressing machines, cafeteria trays, bearings, food and other containers, switches and electrical components, aircraft accessories, etc. Corrosion and exposure tests on new manufactured products and for the appraisal of various protective finishing schemes for structural work have also been conducted.

United Steel Win "The Accountant" Award

THE report and accounts of The United Steel Cos., Ltd., for the year ending September 30th, 1956, were selected for one of the two annual awards for 1957 made by *The Accountant*. The award, which takes the form of a pair of silver hand-made wall sconces, was presented by the Lord Mayor of London, Alderman Sir Cullum Welch, to Sir Walter Benton Jones, the chairman of United Steel, at a Mansion House ceremony on June 18th.

Scalping of Aluminium Ingots

New Holroyd Machine at Banbury



As part of a modernisation scheme designed to provide increased production and efficiency at their Banbury Works, Northern Aluminium Co., Ltd., have just installed a new aluminium ingot scalping machine, the first of its kind to be manufactured in this country, which, when in full production, will replace a complete bay of eleven small scalping machines. Introduced primarily to scalp, that is, remove the rough oxide surfaces from the faces of cast ingots weighing up to $1\frac{1}{4}$ tons (beyond the capacity of any of the existing scalping machines) prior to hot rolling, the entire unit comprises the scalping machine and travelling work-table together with three auxiliary units—an ingot loading table, a scrap conveyor and crusher, and a centrifuge oil remover.

Requirements to be Met

Some of the problems that had to be overcome in the design of this machine were :—

(1) The cutting head had to be suitable for machining both " soft " and " hard " alloys.

(2) Suitable mechanical handling was necessary to enable an ingot to be turned over quickly after machining one side to enable the other side to be dealt with similarly.

(3) Some means of continuously removing the swarf from the cutting tools combined with the avoidance of " mixed " alloys was required.

(4) Suitable machinery was necessary to reduce the size of the pieces of swarf to easily manageable proportions.

(5) The oil adhering to the swarf after the cutting operations had to be removed to enable the swarf to be re-melted and used again.

The scalping machine, which in effect, is a horizontal spindle face milling machine, was designed and constructed by John Holroyd & Co., Ltd., to the particular requirements of Northern Aluminium. The machine has a cutting head comprising 32 roughing tools and two finishing tools set on a five-foot pitch circle diameter driven by a 400 h.p. A.C. motor at a constant speed of 245 r.p.m. A travelling work-table holds the ingot (with the long sides horizontal and the faces vertical) by four hydraulic clamps which, driven by a 4 h.p. A.C. pump, bite on its edges, and carries it across the faces of the blades. The work-table itself is driven by a 25 h.p. A.C. motor through an angular pinion and rack that ensures a smooth drive.

The ingot crosses the cutting head at a speed variable from 5 to 15 ft./min., dependent upon the alloy of the ingot being scalped. The depth of cut, generally about $\frac{3}{16}$ in., is controlled by a stylus pre-set to the required cut. Just before the ingot reaches the cutting head, the work-table stops and the stylus moves up to touch the surface of the ingot, and so determines the position of the blades relative to the ingot surface ; the head is then clamped on to its bed and the stylus is withdrawn. On completion of the scalping of one side the cutting head is withdrawn and the table returns to the loading position at a speed of 60 ft./min.

The loading table, on which the ingot is originally placed by means of an electrically-controlled grab, was also designed by Northern Aluminium Co., Ltd., to turn over the ingots to enable the reverse side to be scalped. The table consists of a series of rollers that can be tilted to roll the ingot either towards or away from the scalper, and is hinged so that it splits into two parts ; by raising both parts together, the ingot, initially lying flat on one of them, is raised on edge and allowed to descend on the other section with the opposite face uppermost. The ingot can then be rolled to the work table, where a forked leaf at the end of the loading table tilts through 90° and presents the ingot in a vertical position ready for clamping. The loading-table, hydraulically operated, was manufactured by R. Goodwin & Sons, Ltd.

Scrap Disposal

The scrap, or swarf, from the scalping falls into a sump below the cutting head, where it is carried on a horizontal conveyor, driven by a 20 h.p. A.C. motor at 960 r.p.m., to a hammer type crusher, built by British Jeffrey-Diamond, Ltd., and driven by a 50 h.p. A.C. motor developing 900 r.p.m. The conveyor receives 80 lb. of swarf in 20 seconds once every two minutes, and conveys this at a rate of 2 tons/hr. to the crusher, where the scrap is reduced to more easily managed lengths before it is emptied into buckets fixed in a vertical elevator, made by W. W. Brown & Partners, Ltd., and driven by a 3 h.p. A.C. motor ; these buckets lift the scrap above ground level, and empty it down a chute into a perforated basket which, when full, is fitted inside a 48 in. diameter oil separator of the U.S.E. type to spin out the oil from the scrap. After a few minutes

in this separator, the basket is removed, using lifting tackle and an overhead track, and the scrap is then ready for re-melting.

The maximum size of ingot that the scalping unit can handle is 72 in. × 54 in. × 10in., and this size can be scalped on both sides at a rate of ten an hour. Simple to operate, the machine can be worked by two men, although for full efficiency a complement of three is necessary. All controls are operated by one man from a control box ; this man can also load and unload the ingots if necessary, but the help of an assistant is desirable. A third operator looks after the oil separator and scrap disposal. The unit will eventually replace a bay of eleven small lathe-type scalping machines, each operated by one man and scalping about 14 half-ton ingots per eight hour shift, and will come into full operation when the installation of a new hot mill designed to take 1-ton ingots is completed.

The new machine will not only fulfill the need for a larger capacity machine, but will also give a greater rate of production and increased efficiency as well as easing the tasks of the operators ; its introduction marks another stage in the modernisation scheme at Banbury Works.

Using Computers in the Iron and Steel Industry

IN the belief that electronic computers will play a large part in the iron and steel industry, the British Iron and Steel Research Association is installing a computer so that practical experience can be gained quickly. B.I.S.R.A's computer will be used to explore the potential applications of computers in the iron and steel industry, and to help individual companies to assess the results they may expect to obtain from machines of their own.

Electronic computers are not near-magical machines that can perform almost any task, nor are they merely mathematicians' playthings. If their operation is complicated, that is primarily because they are generally used to perform calculations that are themselves complicated. But to use a computer does not require a knowledge of advanced electronics—any more than it is necessary to know anything about wireless theory to tune in the radio and hear the six o'clock news.

A great deal of fresh thinking is called for when computers are introduced into an industry, and the best results cannot be obtained by slavishly following the procedures that were devised to suit the limitations of human beings.

Much new ground will have to be broken in applying computers to the steel industry, but there is a considerable fund of experience to draw upon. B.I.S.R.A's own staff have made use of the computer at Manchester University during the past three years for calculations on ironmaking, steelmaking, and operational problems, and various companies within the industry have small groups working on the subject and have computers on order. There is also the experience of other industries : aircraft designers are using computers for their calculations and already have several machines working or on order ; and J. Lyons and Company have installed a computer to mechanise and speed up some of the laborious routine operations entailed in ordering goods and calculating wages.

In the steel industry, as in many others, the potential applications for computers are in research, in mechanising clerical work, and in the integration of computers with production units.

In research the B.I.S.R.A. computer will be able to take over many routine tasks, such as statistical analyses of the results of experiments and many other kinds of data. Trained scientists will thus be freed for less repetitive and more creative work.

A more exciting prospect is offered by using the computer to tackle problems that have so far remained unsolved because of the sheer length of the calculations entailed. Heat flow and temperature distribution in steel and in furnaces present many problems of this kind. By bringing within the realm of practical possibility what would once have been regretfully abandoned, a computer can thus extend the scope of research.

The second, and ultimately more important, use of the B.I.S.R.A. computer will be to study the new uses of these machines in the iron and steel industry. Functioning as a central " pilot plant " for the industry as a whole, it will be used to obtain the working knowledge necessary to put computers into service in steelworks.

It is impossible to predict the influence computers may eventually have in management. Nevertheless, it is clear that for some purposes they will eventually replace punched-card equipment and other mechanical accounting machinery, for they are much faster and have greater capacity and versatility, although they require no more operators.

Two important uses of electronic computers in the steel industry are likely to be the scheduling of production (including receiving orders and forecasting deliveries) and stock control. Other applications include calculating wages and analysing, recording, and costing production. In many applications, if a computer is to be exploited to the full, all the information required should be recorded automatically at the point at which it originates.

The B.I.S.R.A. computer will be installed later this year. Meanwhile, the Computer Applications Section of the Operational Research Department is preparing programmes for use with it and is studying possible industrial applications.

Giant Plate Stretching Machine

FIELDING & PLATT, LTD., of Gloucester, have received a contract for the supply of the very large plate stretching machine which, as recently announced, is to be installed by James Booth & Co., Ltd., manufacturers of Duralumin and other non-ferrous alloys. This new machine will enable plates exceeding 200 sq. in. in cross section to be stretched, compared with a maximum size of about 65 sq. in. on existing equipment. The purpose of the stretching process is to free the plates from internal stress induced by heat treatment, and so to ensure that they do not distort when they are machined. In recent years this has become very important to the aircraft industry, owing to new methods of construction which involve machining components of complex shape out of large thick plates.

NEWS AND ANNOUNCEMENTS

Iron and Steel Institute Meeting in Belgium and Luxembourg

The Iron and Steel Institute is holding a Special Meeting in Belgium and Luxembourg from June 18th to 28th, 1958. In honour of the Institute's visit, the Centre National de Recherches Metallurgiques, the Groupement des Industries Siderurgiques Luxembourgeoises, and the Groupement des Hauts Fourneaux et Acieries Belges are organizing an International Iron and Steel Meeting on the general theme of " New Developments in Iron and Steel Making."

A provisional programme has been prepared for the technical sessions, the first of which will be held in Liege on Wednesday and Thursday, June 18th and 19th, 1958. The four sessions will be devoted, respectively, to the bottom-blown converter, top-blown oxygen processes, steelmaking in the open-hearth furnace, and large arc furnaces. Iron manufacture will be the general theme of the papers presented at the technical sessions in Luxembourg on Monday and Tuesday, June 23rd and 24th, 1958. The topics to be dealt with include low-shaft furnaces, new direct processes, blast-furnace burden preparation, and new techniques in blast-furnace operation. The final technical session at Charleroi on Friday, June 27th, will be devoted to continuous casting, when the theory of continuous casting and development of experimental machines will be considered at the first session, and industrial applications of continuous casting at the second.

Apart from the technical sessions, a number of works visits and social functions will be arranged.

National Committee for Non-Destructive Testing

In recent years the subject of the non-destructive testing of materials has achieved great importance. Societies have been formed with this as their main interest, while other institutions of longer standing have devoted a more or less substantial part of their technical programmes to the discussion of non-destructive testing principles and techniques. At the beginning of this year a combined appeal was made by a number of societies to the Joint Committee on Materials and their Testing to foster the establishment of a National Committee as a focus in the United Kingdom for all interest in this aspect of testing. The Joint Committee accordingly set up a Sub-Committee to examine this request and, as a result of its recommendations, it approved, on June 18th, the constitution, terms of reference and rules for a committee which will be known as " The British National Committee for Non-Destructive Testing."

The formation, at this time, of a British National Committee for Non-Destructive Testing, is of considerable significance, particularly in view of the coming international conference in Chicago in November, 1957. The need for a co-ordinating body has been clearly evidenced by the weight of the joint appeal for its formation, and by the widespread interest which has been shown in the exploratory discussions.

Applications for membership of the British National Committee are invited from institutions or societies with an interest in non-destructive testing : the subscription is five guineas per annum. Each member society will be asked to nominate a representative who would take part in meetings of the National Committee. Applications, for the time being, should be made to the Secretary of the Joint Committee on Materials and their Testing, Mr. R. Main, at 1, Birdcage Walk, Westminster, London, S.W.1. Pending an election, the Chairman of the British National Committee will be Mr. C. H. Stanger, who took the Chair of the Investigating Sub-Committee mentioned above.

The Production Exhibition

The third biennial Production Exhibition, which deals with methods of increasing productivity in industry, will be held in the Grand Hall, Olympia, London, from May 12th–21st, 1958. The Rt. Hon. the Earl of Halsbury the incoming President of the Institution of Production Engineers, will be President of the Exhibition.

This event acts as a clearing house for ideas in every kind of industrial activity, such as : research and development ; training and careers ; improved machinery and methods of production ; electronics in production ; services and aids ; nuclear energy ; metals and alloys ; industrial finishing ; and distribution. Those who have taken part in the two previous exhibitions report considerable increase in their industrial contacts, resulting in a powerful stimulus to business. Enquires should be made to : The Production Exhibition, 32, Millbank, London, S.W.1. (Tate Gallery 8134)

Mechanical Engineering Congress

The Trade Associations of the Mechanical Engineering Industries of Austria, Belgium, Denmark, Germany, Great Britain, Finland, France, Italy, Luxemburg, Netherlands, Norway, Spain, Sweden and Switzerland, which constitute the Organising Committee, have deputed to Vereniging van Metaal Industrieen, The Hague, the responsibility for organising at Scheveningen from June 2nd to 6th, 1958, the Seventh International Mechanical Engineering Congress. One of the main objectives of the Congress in 1958 will be the examination on a wide international plane of matters currently influencing manufacturing progress, both in the technical and economic spheres. The working sessions will be conducted in English, French or German, and difficulties of translation will be obviated by a simultaneous interpreter service.

I.P.E. Materials Handling Group

It is announced by the Institution of Production Engineers that a specialist Group on Materials Handling has been formed within the Institution, under the chairmanship of Mr. A. G. Hayek, of A. G. Hayek and Partners, Ltd., Stoke-on-Trent. The purpose of the Group is to provide a central forum for those members of the Institution having a special interest in materials handling, which for this purpose is defined as : " the

study of the handling or other movement of materials before, during or after processes in every type of industrial activity. This study shall be directed particularly to minimising or mechanising such movement." The main activities of the Group will be the organisation of conferences and lecture meetings, where original papers on materials handling may be presented; the preparation of case studies for publication; the establishment of working groups; and in other ways the stimulation of interest in and the building up of a body of knowledge of materials handling directly and by liaison with other bodies.

A New Translation Service

ENQUIRIES have shown that there is a growing need in the iron and steel industry for improved facilities for obtaining translations of foreign technical literature, including Russian. The Iron and Steel Institute has been investigating this problem and, at the suggestion of the British Iron and Steel Research Association, has agreed to organise a co-operative translation service.

Plans are already well advanced, and a number of companies in the industry are collaborating with the Institute in setting up the service. The scheme will benefit the industry in two ways: not only will the range of available translations of technical papers be considerably widened, but also much unnecessary duplication of effort will be avoided. Translations prepared by individual companies will be passed to the central pool and these will be supplemented by translations from other sources. Among the foreign technical journals from which the translations will be prepared are *Stal*, *Ogneupory* and *Koks i Khimiya* (Russia) and *Arch. Eisenhuttenwesen* and *Stahl u. Eisen* (Germany).

Although primarily devised to serve the needs of the iron and steel industry, the new service will nevertheless be available to all who wish to take advantage of the facilities offered. An agreed scale of charges has been laid down which includes provision for substantial reductions where a number of copies of any individual paper are required.

An index is currently being compiled of those translations made since 1950 which are still available, and lists of newly produced material, and news of translations in course of preparation, will be circulated among their members and published at regular intervals by B.I.S.R.A., the British Iron and Steel Federation, and the Institute itself. The production of the index is well advanced, and on completion a further announcement will be made, inviting applications for full details, price lists, etc.

Continuous Casting Agreement

An agreement has been concluded between Concast Co., Ltd., Zurich, and Dollery & Palmer, Ltd., 54, Victoria Street, London, S.W.1, under which Dollery & Palmer will represent the Swiss firm in the United Kingdom. Concast, in combination with Continuous Metalcast Co., Inc., of New York, sell and licence the operation of continuous casting machines throughout the world according to the Rossi-Concast process. Machines are now in commercial operation casting steel and non-ferrous metals in England, U.S.A., Canada, France, Sweden and Japan. At the present time additional machines are under construction in several other countries.

Common Research on Metal Fatigue

A LARGE proportion of failures of machine components are due to fatigue, and it is necessary, therefore, for designers to know precisely the effects of stress fluctuations on the life of a component which, during its life, goes through successive periods of overloading, light-loading and rest. If all the factors influencing the failure of the component are taken into account, the number of tests to be carried out appears to be so high that one laboratory working alone would have to devote itself to the task for nearly a decade. For this reason, an international working party of the O.E.E.C. European Productivity Agency has set up a wide programme of common research.

Experiments aimed at determining the damage by fatigue will be shared between research laboratories in Belgium, Canada, France, Germany, Italy, the Netherlands, Sweden and the United Kingdom.

Computor Controlled Flame Cutting

AN extensive twelve month's research co-operation between the British Oxygen Co., Ltd., and Ferranti, Ltd., has resulted in revolutionary advances in the field of computer controlled flame cutting machines. The new equipment which will result from this link-up is believed to be the first of its kind in the world, and will have far-reaching application in all branches of heavy engineering and particularly in atomic energy and chemical engineering. It will be of the greatest interest also to the shipbuilding industry where, it is anticipated, there will be notable reductions in time and cost in the preparation of ships' plates.

The new system is essentially an application of Ferranti machine tool control methods to new developments by British Oxygen in the field of oxygen cutting. As well as fully automatic operation of the profiling process, the system includes special features for controlling automatically the gas supplies to the cutting blow pipes, automatic ignition, pre-heat flame monitoring, nozzle-height sensing and cutter head rotation. Demonstrations of the first experimental machine are expected to take place in the Autumn of this year.

C.R.L. Open Days

THE work in progress at the Chemical Research Laboratory, Teddington, may be seen during a series of Open Days to be held from Tuesday to Thursday, October 1st to 3rd, 1957. Applications from firms for invitations to the following sessions should be sent to the Director not later than August 31st, 1957: Tuesday, October 1st—afternoon only—2-30 to 5-30 p.m.; Wednesday and Thursday, October 2nd and 3rd—morning 10 a.m. to 1 p.m., afternoon 2-30 to 5-30 p.m. Firms already on the mailing list for invitations need not re-apply.

The "Dip. Tech." and Production

THE Department of Industrial Engineering of the Loughborough College of Technology is pleased to announce that the National Council for Technological Awards has recognised the first four years of their five-year Sandwich Course as leading to the Diploma in Technology (Dip. Tech.(Eng.)) in Production Engineering.

This course in pure production engineering is intended

to prepare student-apprentices for posts of responsibility, as production technologists or in management, in the metal-working industries. The subjects of the fourth-year (Dip. Tech.) examination are: industrial metallurgy—plasticity; industrial metallurgy—molten metal; industrial metallurgy—welding; theory of machine tools; tool design; metrology; work study; applied statistics and operational research; industrial psychology; industrial and commercial law. The course continues into a fifth year for the award of Associate of Loughborough College (A.L.C.) when the subjects of examination are work study; personnel management; financial management; higher business control; factory management; product development; design and distribution; synthetic materials; technology of automation.

Under the sandwich plan students spend six months each year in College and six months working as industrial apprentices. A number of nationally-known companies operate student-apprenticeship schemes in connection with these courses and are prepared to receive applications from suitable qualified youths. Further particulars may be obtained from the Head of the Department of Industrial Engineering, Loughborough College of Technology, Loughborough, Leicestershire (Tel.: Loughborough 4428).

Brazing Conference

ORGANISED by the Department of Industrial Metallurgy, a Conference on the Wetting and Spreading of Liquid Metals on Solid Metal Surfaces will be held at Birmingham University on Wednesday, September, 25th 1957. The Conference will be opened by PROFESSOR E. C. ROLLASON at 10 a.m., and will include four papers on various aspects of the subject, followed by a general discussion. Applications for enrolment should be addressed to the Secretary, Department of Industrial Metallurgy, University of Birmingham, Edgbaston, Birmingham 15, and marked "Brazing Conference." An enrolment fee of 15s. will be charged, and will include the cost of lunch and refreshments.

Nuclear Contract for TI Company

A CONTRACT worth nearly £¾ million has been received by the Tube Investments subsidiary, Talbot Stead Tube Co., Ltd., from C. A. Parsons & Co., Ltd. (a member of the Nuclear Power Plant Co., Ltd.), for specialised atomic reactor components for the Bradwell nuclear power station in Essex. The order includes fuel element support assemblies, charging standpipes, neutron source assemblies, absorber rods, short charge plugs, control rods, and control rod standpipe plug assemblies.

New British Process for America

A NEW British process for soft soldering aluminium will be introduced into the United States and Canada following an agreement between the inventors, Tiltman Langley, Ltd., of Redhill Aerodrome, Surrey, and Reynolds Metals Company of U.S.A. The T.L. Process, which is corrosion resisting and fluxless, stems from investigations into the difficulties of soft soldering aluminium and its alloys carried out on behalf of the Ministry of Supply.

Special solder is one of the key factors in this process, which reduces what was a complicated operation to the handyman level. In addition to the wide industrial applications, one of the main objectives of the agreement will be to introduce the process to the vast American "do-it-yourself" market. One outstanding advantage of the British process is the simplicity of materials and method: a simple hand tool gives joints having a shear strength of 2½ tons/sq. in.

Leading metal manufacturers in France, Belgium and Sweden are negotiating for exclusive rights in their home and overseas markets.

New Contracts for British Oxygen

AMONG orders placed recently with British Oxygen Gases Ltd., is one for 51 sets of the new Saffire oxy-acetylene hand welding and cutting blowpipes together with spares and servicing tools which will be used for work on the Kuwait Oil Refinery extension.

Work on the extension is being carried out under the American supervision of Betchtel Wimpey, Ltd., an associate company of George Wimpey & Co., Ltd. The order is worth about £2,300. A further order, valued at 83,000 dollars (over £30,000), has been secured from the U.S. Navy, for equipment to be used in N.A.T.O. dockyards in Spain. Included in the order are two Bison oxy-acetylene cutting machines, each 84 in. wide and 378 in. long, with accessories; and 10 Bantam cutting machines, with 12 ft. lengths of track. Another order has been placed from Sweden for 100 Saffire 18 in./90° cutters, 25 heavy duty cutters (27 in./75°) and accessories. The value of this order is £1,770, and the equipment has been ordered by Aga Svenska A.B. Gasaccumulator Lidingo, of Stockholm.

New Stretcher-Detwister at Southern Forge

THE reorganisation and extension of their aluminium alloy extrusion plant at Langley announced last year by Southern Forge, Ltd. is now well under way. One of the first new pieces of equipment to come into service is a 250-ton stretching and detwisting machine which is already proving a valuable addition to the existing stretchers in handling the larger and more complicated sections now in demand for commercial vehicle bodies, curtain walling and structural applications.

The machine will straighten and detwist extruded sections that may be enclosed within a circle of 16 in. diameter, and up to a maximum length of 45 ft. The main 250-ton ram has a stroke of 5 ft., and the detwisting head can be rotated through 135° in either direction. The stretcher was designed and manufactured by Fielding and Platt, Ltd., in co-operation with Southern Forge engineers.

Amber Oil Products Distribution

AMBER OILS, LTD., announce that the world distribution of their pressurised dispenser products, Aerozene (penetrating oil and spring lubricant), Blink (invisible metal protector), and Rusolvent (easing fluid), have now been taken over by Slip Products and Engineering Co., Ltd., of 34, Great St. Helen's, London, E.C.3 and St. Albans. Ambersil (silicone mould release and anti-stick agent) and Ruby (industrial protective lacquer) will continue to be handled by Amber Oils, Ltd.

Tyne Ore Quay Extensions

Mr. A. G. Everett, Chairman of the Tyne Improvement Commission, foreshadowed big extensions at the iron ore quay in his report to the Annual Meeting of the Commission recently held in Newcastle. He disclosed that, at the request of the Consett Iron Company, plans are now in hand to enlarge the plant. Additional ore is necessary to meet the needs of a new blast furnace which is expected to be in operation at Consett within the next three years. It is understood that an extension of the ore quay into the existing Sutherland Quay is contemplated, to enable two ships to be discharged simultaneously instead of one as at present. This will mean additional cranes, greater hopper storage capacity set back from the quay, and an increased ore train service between the dock and Consett.

The present discharging plant was completed in November, 1953. It was expected to have an annual capacity of $1\frac{1}{4}$ million tons, but this figure is being exceeded; last year, for instance, 1·4 million tons of ore were handled. The extension contemplated is to raise the discharging capacity to $2\frac{1}{2}$ million tons annually.

Iron ore imports have continued at a high level, and the port has the highest overall daily discharge rate in the country. During the first week in June a record was created with the discharge of 8,511 tons of ore in six hours. Large vessels can present considerable problems to port authorities, but the Tyne is quite well placed in regard to access. Most of the river has adequate depth of water, and even to Newcastle Quay there is 40 ft. in the channel at spring tides.

Largest Scrap Baling Press

A giant press which will reduce two tons of scrap iron and steel—the weight equivalent of seven motor-car bodies—to a neat compact block of about 3 ft. wide, 2 ft. deep and 4 ft. long, began operations recently at the Rotherham works of Steel, Peech and Tozer, a branch of The United Steel Cos., Ltd. Costing £150,000 to instal, it is the largest scrap baling press in this country, and is capable of handling 3,500 tons of material a week. After charging with scrap, hydraulic rams apply a pressure of 5,000 lb./sq. in. to the load in three directions successively, the compressed bale being ejected automatically at the end of the third compression. The entire operation of this German-made machine is controlled by one operator. Because a greater weight of baled scrap can be charged into open hearth steel melting furnaces in the same time as lighter, unbaled scrap, the effect of this new installation will be to reduce furnace charging times, and thus increase steel output.

British Oxygen North-East Expansion

Due to the rapid expansion of industries in the North-East, British Oxygen Gases, Ltd., are building a new factory at Grangetown, Middlesbrough, at an estimated cost of £$1\frac{3}{4}$ million. The new plant, built by British Oxygen Engineering, Ltd., will produce compressed and liquid oxygen, and liquid and tonnage nitrogen (which will be fed, after purification, by pipeline to the I.C.I. factory at Wilton). A plant capable of producing 200 tons of gaseous oxygen per day will also come into operation at a later date. Other industrial gases manufactured by the Company will also be distributed from Grangetown. The activities of the British Oxygen factory at Billingham have been transferred to the new site, which comprises 20 acres.

British Industries Fair

The Birmingham Chamber of Commerce, which has been responsible for the organisation of the British Industries Fair at Castle Bromwich for some years, has decided not to hold a Fair at all in 1958. It will be recalled that the London sections of the Fair were not held this year. The Chamber is in favour of putting the Fair on an international basis, and it would be impracticable to stage an international fair in the time available. After hearing an explanation of the present position from a deputation from the Chamber, the President of the Board of Trade, Sir David Eccles, said that in his view the question of internationalisation in future years must depend primarily on the attitude of British industry.

World's Largest Radio Telescope

Towering as high as Nelson's column above the Cheshire countryside, the world's largest radio telescope at Jodrell Bank, near Manchester, was handed over recently to the radio-astronomers who will use it for probing the mysteries of outer space, a thousand million light years away.

Built to the order of Manchester University, jointly with the Department of Scientific and Industrial Research, the steerable paraboloid altazimuth radio reflector—to give it its full title—consists essentially of a 250 ft. diameter reflecting surface cradled in a bowl of structural steelwork, this structure being pivoted between two 180 ft. high steel lattice towers. The towers are supported on bogies travelling on a 352 ft. diameter circular railway track, so that the whole 1,800-ton substructure—1,000 tons for the lattice towers and 800 tons for the bowl—can be rotated slowly through 360°, while the bowl can be rocked between the towers and trained on any point in the sky. Radio waves reflected from the concave surface of the bowl are focused on an aerial at the top of a 55 ft. lattice tower rising from the lowest point in the bowl. Suspended below the bowl is a laboratory which remains on an even keel throughout all motions of the bowl on its trunnions.

Designed by Husband and Co., consulting engineers, of London and Sheffield, the structural steelwork for the radio telescope was fabricated by United Steel Structural Co., Ltd., of Scunthorpe, a subsidiary of The United Steel Cos., Ltd. Although the tonnage of steel involved is not exceptionally large, the unique nature of the contract called for meticulous care in the preparation of the drawings and in the fabrication of the steelwork, the bulk of which had to be assembled on site.

Rutherford Memorial Lecturers

Professor E. N. da C. Andrade, F.R.S., has been appointed Rutherford Memorial Lecturer for 1957, to deliver the lecture in Australia during September-October, and Professor P. M. S. Blackett, F.R.S., has been appointed for 1958, to deliver the lecture in Canada.

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Boiler-Level Control

A "THREE-ELEMENT" drum water-level control system, utilising standard instruments and components, is now available as an integral part of any automatic-boiler-control scheme produced by George Kent, Ltd., for water-tube boilers. The three elements taken into consideration by the scheme refer to the three measurements: of feed-water flow, steam flow and drum water-level, all of which are essential for the efficient control of the amount of water in the drum, regardless of the most severe plant fluctuations.

In a modern water-tube boiler, the ratio of water content to heating surface is small, and therefore it is necessary to restrict variations in the drum water-level as much as possible. For an increased steam demand it can be seen that it is necessary to: (*a*) increase the feed-water flow to balance the higher steam flow; (*b*) decrease the feed-water flow to correct the instantaneous rise in water-level owing to the fall in drum pressure. The Kent "three-element" control scheme caters for these two conflicting requirements by combining drum-water-level control with steam-flow/feed-water-flow ratio control. These controls both act by regulation of the flow of feed water, and the extent to which one predominates over the other can be adjusted to any value between pure level control and pure flow-ratio control.

The system makes use of four instruments, a drum-level transmitter, a steam-flow transmitter, a feed-water-flow instrument fitted with a computing and transmitting mechanism, and the master instrument of the scheme, a level controller. The steam-flow instrument transmits a pneumatic signal, proportional to the value of steam flow, to the feed-water-flow instrument. The latter measures the water flow and transmits a signal, which represents the difference between steam flow and water flow, to the master level controller. This controller also receives a signal, proportional to level, from the drum-level transmitter. In the master level controller, the control mechanism operates in response to the difference between the level signal and the steam-flow minus water-flow signal, and sends a corresponding control signal to the feed-water regulating valve.

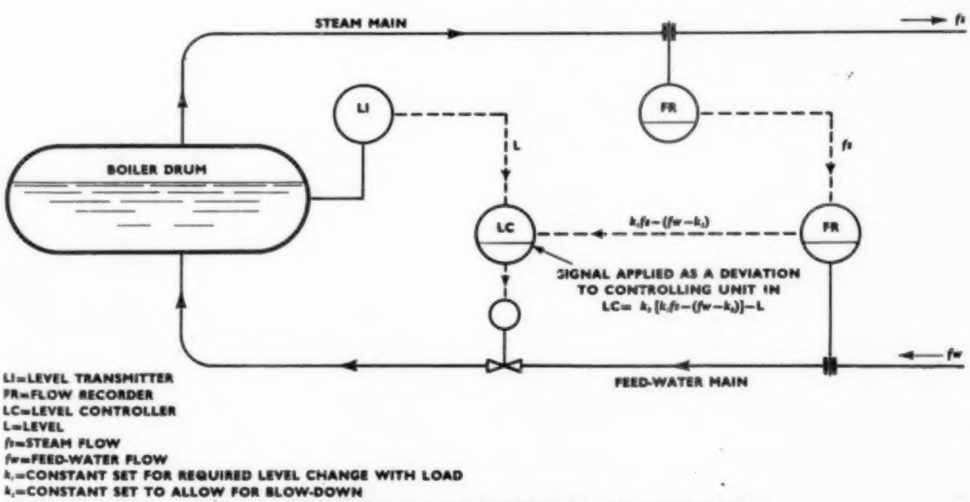
The Kent three-element control system is very flexible and can readily be adjusted to match the operating characteristics of the boiler plant. It is possible to set: (*a*) the amount by which the level changes with a given change of load; (*b*) the balance between flow-ratio control and level control; and (*c*) the value of a constant which is introduced into the water-flow signal to allow for blow-down.

The drum-level transmitter measures the level by the differential-pressure method and is a mercurial U-tube instrument. A special design of detecting element, which is claimed to be an improvement on any used in the past, eliminates errors due to thermal gradients within the pressure pipes. An air-operated transmitting unit is incorporated in the instrument and provides a means of making allowance for the steam density under boiler-operating conditions. The water and steam-flow instruments are also of the mercurial U-tube differential-pressure type and incorporate air-operated transmitting and computing units of the Mark 20 range. All the instruments used in this control system are production models from the Commander range.

George Kent, Ltd., Luton, Beds.

Ten-Speed Multi-Purpose Bandsaw

THE "Volant" bandsaw has recently been added to the range of light machine tools manufactured by the Startrite Engineering Co., Ltd. With its ten-speed control of continuous cutting narrow saw bands, the



machine has been designed to utilise to full advantage the time and material saving factors of band machining. It is capable of machining to shape a wide range of industrial materials such as brass, plastics, wood, aluminium, cast iron, mild steel, tool steel, etc. The machine throat capacity is 18 in., depth under guides $5\frac{3}{4}$ in., and speed selection 56 to 3,200 ft./min.

A large hinged door provides ample clearance when changing tools, and the steel disc band rolls are rapidly interchangeable for tyre service. The upper wheel includes blade tensioning and tracking gear. The 20×19 in. cast iron work table swivels 45° right and 5° left, on a dual trunnion casting. A tee-slot is machined in the table apron face to carry a fence attachment with fine screw control. Designed to provide maximum tool support and work visibility, the tool guide posts include hardened and ground ball bearing thrust rollers with steel inserts for lateral blade support. Guide pieces are adjustable throughout by fine screw control. Easy access to the lower guide block is provided through a large disc-type table insert.

The welding apparatus built into the machine is automatic in operation and includes a motorised weld grinder, blade squaring shear and annealing switch. A low-voltage spotlight and an air jet operated from a small air-pump are suitably located at the work station. The job selector dial built into the machine, gives the operator all factors for most efficient machining. It shows type an l speed of tool to be used for the composition and thickness of material to be machined. The machine is worked with a band tool 95 in. long, from $\frac{1}{16}$ in. to $\frac{1}{2}$ in. wide.

Startrite Engineering Co., Ltd., Waterside Works, Gads Hill, Gillingham, Kent.

Protective Coating for Metal Components

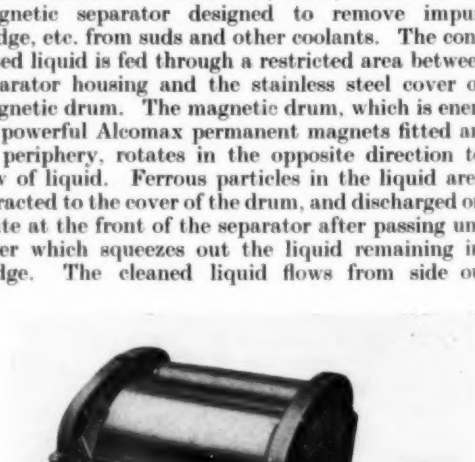
Ruby, a hardened resin type of lacquer, packed in an Aerosol container for use in industry, is announced by Amber Oils Ltd. When sprayed on metal surfaces it forms a hard corrosion-inhibiting coating, which is red in colour for easy examination and economy of application. This coating is strongly resistant to scuffing and abrasion, and will not crack in conditions of heat and moisture. Once applied, it will remain intact for a very considerable period. It can, however, be removed by readily available solvents, such as paraffin or white spirit. One tin of Ruby will give a guaranteed minimum coverage of 150 sq. ft.

In a product evaluation test recently carried out by a major manufacturer of engineering components, sample pieces of shim steel were vapour degreased, sprayed with one coat of Ruby and suspended by iron wires in various positions subject to outside atmospheric conditions, inside atmosphere, acid fumes, acid fumes and dampness, mild acid solution, and alkali fumes and water vapour. The firm concluded in their report that Ruby gave protection against fairly severe corrosive conditions for a considerable length of time; it was described as " one of the best rust preventives we have tested recently, and its packaging and method of application have much to recommend it."

Amber Oils, Ltd., 11a, Albemarle Street, London, W.1.

Coolant Separator

Rapid Magnetic Machines, Ltd., announce a new magnetic separator designed to remove impurities, sludge, etc. from suds and other coolants. The contaminated liquid is fed through a restricted area between the separator housing and the stainless steel cover of the magnetic drum. The magnetic drum, which is energised by powerful Alcomax permanent magnets fitted around its periphery, rotates in the opposite direction to the flow of liquid. Ferrous particles in the liquid are thus attracted to the cover of the drum, and discharged on to a chute at the front of the separator after passing under a roller which squeezes out the liquid remaining in the sludge. The cleaned liquid flows from side outlets



located near the front of the separator, and is then ready to be re-circulated. Magnetics adhering to the drum face form a mechanical filter which also collects non-magnetic abrasive particles. For ease of cleaning, plugs are suitably located on the machine where sludge may collect.

These equipments are available in a wide range of capacities from 10 gal./ min.—in increments of 10—to approximately 40 gal./min. The only power supply needed is that for the motor which drives the magnetic drum. The use of this type of equipment has been proved to produce increased tool and wheel life, less coolant loss and consequent increase in life ; also a higher standard of finish is obtained. This equipment can also be adapted for extracting ferrous impurities from other liquids, including lubricating oils, potters' slip, chemicals, paints, etc.

Rapid Magnetic Machines, Ltd., Lombard Street, Birmingham 12.

Nickel Stripper

United Chemical Corporation of New England, is now marketing a new nickel stripper (patent pending) called Ni-Plex, which contains no cyanide, caustic or acid, does not fume, and is stable over long periods of time at elevated temperatures. It is claimed that it strips nickel economically and rapidly from all basis metals such as steel, copper, brass, and is effective and safe for all type of die castings, and for parts containing two or more different basis metals. It does not pit or corrode the basis metal.

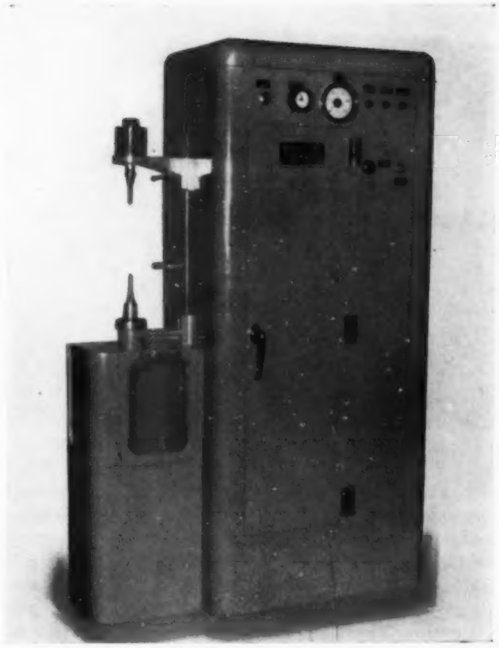
The product is marketed in two solutions, as Ni-Plex A and Ni-Plex B, which are easily mixed and diluted to proper strength. The bath is operated at from room temperature to 80° C. at a pH of from 7 to 11. One gallon of Ni-Plex bath will strip over 40 sq. ft. of 0·0001 in. nickel plate. The stripping rate at room temperature is 0·00025 in./hr. ; at 80° C. the rate is 0·0015 in./hr. One advantage claimed for Ni-Plex is that it enables platers to maintain one stripping bath in continuous operation for the removal of nickel from all basis metals.

United Chemical Corporation of New England, 45, *Seekonk Street, Providence* 6, *Rhode Island, U.S.A.*

Induction Hardening Fixture

A new type of induction hardening fixture for the progressive hardening of shafts operates on the pneumatic hydraulic principle, enabling smooth speed control of the carriage to be obtained without the expense of a hydraulic pump unit, power being derived from an air supply.

The shaft to be hardened is supported in a vertical position between the two centres shown on the left hand side of the fixture, and the H.F. inductor and quench are located between them, but are not illustrated. The top centre is spring loaded, while the bottom one is driven by an air motor at an adjustable speed, and both are fitted to a carriage inside the cabinet, actuated by a double-acting hydraulic cylinder. Each side of the cylinder is connected to an oil reservoir and air pressure is applied to the top of the oil in each reservoir as required. The speed of the carriage in a downward direction is controlled by a valve in the exhaust pipeline of the carriage cylinder, while the opposite pipeline is



unrestricted, giving a rapid return travel. The carriage runs on linear ball bearings, giving it great accuracy and reliability over long periods, with negligible wear and friction losses. Speed controls are provided on the front of the cabinet, together with a linear speed indicator giving a direct reading of the carriage speed.

After a shaft has been fitted between the centres in the loading position with the carriage at the top of its stroke, the start push button is pressed. The shaft is then lowered at a controlled speed through the H.F. inductor and quench, and the high frequency power is switched on and off at the correct positions, giving the desired hardness pattern. On reaching the bottom of its stroke the carriage automatically returns at high speed to the loading position. Limit switches are provided behind the door on the front of the cabinet, enabling selection of the positions at which the H.F. power is switched on and off, and also of the position at which the carriage is reversed. The whole unit is built into a welded aluminium framework for rigidity, and is capable of being used with any type of H.F. induction heater of adequate output for the size of shaft to be treated.

An electrically operated progressive induction hardening fixture similar to the above, but utilising a PH infinitely variable speed motor controller has also been developed.

Precision Heating, Ltd., 142*a Canbury Park Road, Kingston-on-Thames, Surrey.*

Conveyor Belt Guide

A number of important advantages are claimed for the Guidler, a patented control mechanism for guiding conveyor belts which has recently been introduced to this country, and which has already proved its worth in Scandinavia and in the United States. The disadvantage of the normal straight-sided upright guide

roller is that it offers only point contact to the belt edge. As a result, the belt wears a groove in the roller and becomes confined to the groove, which bends and damages the edge of the belt.

The Guidler employs a hyperole in its design which, when tilted at the proper angle (30°) to the plane of the belt edge, offers a revolving long line contact surface which guides the belt without damage to the edge. Because of lack of rigidity, every working belt has a tendency to oscillate between the carrying idlers, this oscillation being directly related to load and speed. The Guidler combines an axial movement on its spindle with its revolving motion, and this enables it to follow this normal lift motion of the belt while continuing to exercise perfect control over the belt edge.

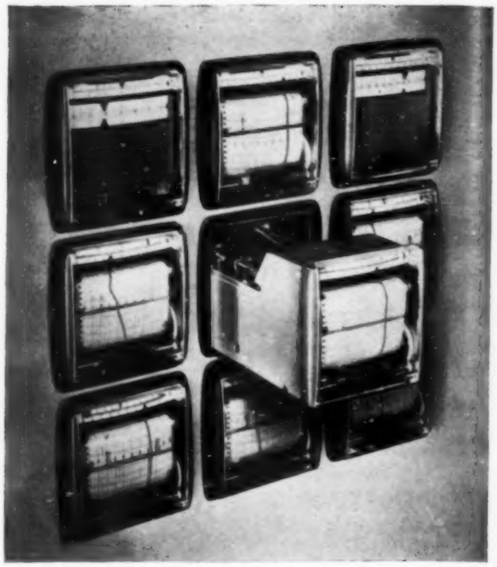
The British Wedge Wire Co., Ltd., Academy Street, Warrington, Lancs.

"Pullout" Recorder-Controller

A recently introduced addition to Foxboro-Yoxall's range of Consotrol instruments is the new M/54 recorder/controller. This instrument is similar to, and performs the same functions as the widely-used and familiar M/53 series, but an important extra facility is introduced whereby the recorder, complete with the controller (when mounted at the rear of the recorder), can be removed completely from the panel whilst the transfer switch is in the "seal" position. The entire unit slides into a sheet steel housing which is secured to the panel and to which are attached all the external connections. These, electric and pneumatic, are of the plug-in type, and when the unit is withdrawn from the panel a series of air check valves automatically close to prevent loss of pressure in the impulse lines.

When the M/54 is used as a recorder controller, the M/58 Consotrol controller, may be integrally mounted with the recorder, and the ease with which the instrument can be withdrawn from the panel simplifies the adjustment procedure. All controller settings are easily accessible from the front of the panel. Rear access to the adjustments is provided by means of a hinged, plastic window at the rear of the M/54 case.

The pull-out feature permits a complete instrument to be replaced without disturbing the process. Since the control system can be transferred from automatic to manual control, the M/54/58 can be removed from the



panel and replaced by a service spare unit on which the setting index and controller settings have been adjusted to agree with the values already obtained. Bumpless transfer using the M/54 auto-seal-manual transfer switch ensures that the system is brought back into completely automatic operation a few minutes after the changeover operation is commenced.

In the M/54 the complete chart drive assembly may be removed from the unit without affecting the process operation. The assembly is removable as a unit and a mercury switch automatically breaks the chart drive circuit. Where a pneumatic chart drive is used a check valve performs the same function to prevent loss of air. The sheet steel housing completely encloses the M/54 mechanism, which is thereby air-purged. This has the advantage of protecting the instrument from harmful atmospheres and increases the safety of operation where an electrical chart drive is used.

Foxboro-Yoxall, Ltd., Lombard Road, Merton, London, S.W.19.

Crushers and Granulators

The Hadfield range of crushers has now been extended to embrace new roller-bearing crushers and granulators. The first three roller-bearing crushers to come off the production line are: (*a*) a 36 × 24 in. Blake-type crusher with sectional (four piece) cast steel frame; (*b*) a 24 × 12 in. Blake-type crusher with one-piece cast steel frame; and (*c*) a 36 × 5 in. jaw type granulator (single toggle) with one-piece cast steel frame.

In the design and construction of these machines the Company's earlier policy has been followed, namely, to give the user a series of really robust crushers which will "stay the course." The roller bearings employed are of the double-row, self-aligning type, by Skefco, and are of really generous proportions. These machines are in their final stage of erection and in accordance with Company policy are undergoing a series of test periods. It is expected that they will be available on the market in the very near future as standard productions.

Hadfields, Ltd., East Hecla Works, Sheffield, 9.

CURRENT LITERATURE

Book Notices

METALLURGICAL PROGRESS

Third Series of Critical Reviews. Published by Iliffe & Sons, Ltd., for *Iron & Steel*. $11\frac{1}{4} \times 8\frac{3}{4}$ in., 88 pp. 6s. post free.

THE success of the first and second series of Critical Reviews both here and in the United States has encouraged the publishers to present a third volume of "Metallurgical Progress." The principle of compilation has remained unchanged; the contributors have searched the literature for the last 30 years, often in several languages, and from their findings have produced a reasoned survey of the current state of research knowledge on their particular subject. As before, the articles present information in concise, easily readable form, which the student could only obtain as the result of many weeks of arduous work.

Third series contains reviews on Refractories in the Iron and Steel Industry, by DR. HELEN TOWERS; Non-Destructive Testing, by DR. J. M. MCLEOD; Metallurgical Coke 1939–1955, by DR. J. TAYLOR; Progress in Foundry Technology: Foundry Sand Practice, by W. B. PARKES; Reducing the Phosphorus Content of Foundry Iron, by R. I. HIGGINS; Ironfoundry Metal Melting Furnaces by FRANK DUNN; and Mechanical Properties of Flake Graphite Cast Iron, by G. N. J. GILBERT.

Because of the steep rise in printing costs, it has been necessary to increase the price of this issue to 6s. post free, but it still remains excellent value.

THE PROCEDURE HANDBOOK OF ARC WELDING DESIGN AND PRACTICE

Completely revised eleventh edition. Over 1,300 pages with 1,100 illustrations, pictures and chart. The Lincoln Electric Company, Cleveland 17, Ohio. \$3.00.

THE eleventh edition of the Procedure Handbook of Arc Welding Design and Practice, recently announced by The Lincoln Electric Company, is a major revision of this well-known arc welding reference book. A large part of the book has been completely rewritten, and all of it has been closely reviewed and brought up-to-date.

The book is arranged and written as a reference book covering all phases of arc welding. Its contents range from the early history of arc welding to the intricacies of structural design. The eight sections are divided by subject matter for easy study. Each section has its own table of contents, and there is a complete alphabetical index for the entire book. The eight sections are: history, nomenclature and processes, weldability, mild steel procedures, manufacturing cost data, machine design, structural design, applications and reference data.

The 465-page structural section has been completely rewritten and includes the latest data on welded design, as found in recently built structures and current research. There is a discussion of the theory and application of the rigid frame and plastic design systems. Details on the design of structural members and joints are included, and a group of charts and nomographs simplify design calculations. Applicable codes have been condensed to usable size and are included.

Another section presents an entire machine design system which directs the designer from his starting point of "what the machine must do" to a completed design. The system is a logical procedure insuring consideration of all pertinent factors and leading to an economical design which puts the right amount of material in the right places.

The weldability section presents information on how to weld all the commonly welded metals, including such new materials as zirconium and titanium. The mild steel welding procedure section gives detailed welding procedures for all joints. These procedures are said to be lowest cost consistent with good quality, and include the new iron powder manual electrodes, as well as new automatic procedures and the latest information on hardsurfacing, carbon arc work, tool and die welding, pipeline, piping and code welding.

Manufacturing cost data includes 28 graphs for estimating the cost of such manufacturing processes as cutting, forming and welding steel. The charts are for use by designers and production men.

DIRECTORY OF OPPORTUNITIES FOR SCHOOL LEAVERS

116 pp. Cornmarket Press, Ltd., 1, Lower James Street, London, W.1. 9s. post free.

EVERY boy and girl leaving school this summer will be able to consult this reference book in which nation-wide employers give detailed information about the careers they have to offer, and which has been prepared with assistance from the Careers Committee of the Incorporated Association of Headmasters and the Public Schools Appointments Bureau. It is introduced by informative articles on careers and professions, and has a preface by Sir John Wolfenden, Vice-Chancellor of Reading University.

The reference section is the main part of the book, and consists of a series of entries from organisations wishing to recruit school leavers. Full details are given about the employment or apprenticeship offered, including location, salaries, prospects and amenities. From the nine-page classified index boys and girls will find the opportunities that exist near their homes for people of their age and educational standard. Thirty thousand copies have been sent free of charge to schools which educate boys or girls up to school-leaving age. Youth Employment Officers, Careers Advisory Officers and the Public Schools Appointments Bureau will also receive a complimentary copy.

This Directory is the second in a series of three annual reference books which are distributed free to those about to choose their first jobs. The "Directory of Opportunities for Graduates" was published in January and sent to all final year students with the co-operation of the University Appointments Boards; and the "Directory of Opportunies for Qualified Men" will be published in November and sent to those qualifying in professional or technological examinations.

Trade Publications

A DESCRIPTIVE leaflet recently published by Albright & Wilson (Mfg.), Ltd., describes Kanigen plate, new hard and corrosion resistant metallic coating for most metals in general engineering use that can also be applied to glass, ceramics and thermo-setting resins. Kanigen chemical nickel plate is a nickel-phosphorus alloy containing about 8% phosphorus. It has extremely low porosity and is hard and wear-resistant. A coating of Kanigen plate on metal parts increases their resistance to wear and corrosion. On ferrous materials the plate prevents contamination of liquids by iron from pumps, pipework, containers, etc. Kanigen plate is used in a wide range of applications in many industries such as those engaged in making aircraft components, chemical and process equipment, automobile parts, etc.

SPECIFICATION sheets covering a number of transducers, the associated power units, and the simple analogue computer have now been produced by Evershed & Vignoles, Ltd. The transducers covered are for flow, pressure, differential pressure and level, and further specification sheets are in course of production. Practical in layout, and authoritative in subject matter, they give sufficient information without "bogging down" the enquirer with too much technical detail. Further sheets containing details of a more technical nature covering the construction and maintenance aspects of each transducer are being produced, and in support of the specification sheets.

THE Control and Electronics Department of The English Electric Company has issued a new publication describing the Deuce universal digital computer and also special purpose digital computers. The Deuce, which is in full-scale production, has been designed for the automatic and high-speed solution of complex mathematical problems associated with modern developments in science and engineering design and production, and it is one of the most versatile and widely used computers of its type. For particular applications, such as the automatic control of processes subject to a number of varying factors, The English Electric Company manufacture special purpose computers which are built up from logical circuits made as standard units, with the appropriate control circuits.

WE have received from Kodak, Ltd., a leaflet dealing with Kodak glazing machines. Of the thermostatically-controlled drum-type machines, the Model 24TC is designed for use in large photographic departments and D. and P. works. It has a capacity of 1,000–1,500 $2\frac{1}{4} \times 3\frac{1}{4}$ in. prints (or their equivalent) per hour. The glazing drum is of mirror-finished stainless steel, as is that of the Model 15TC which has a capacity of 500–600 prints per hour. For the small studio there is a flat bed glazer.

FEATURED in the Summer 1957 issue of *The Turnbridge News*, is a brief description of the Holmes-Catco process of converting objectionable fumes to odour-free gases. A further technical item deals with the inert gas generators manufactured by W. C. Holmes & Co., Ltd., for a variety of industries. The gas is generated by the controlled combustion of fuel gas or oil.

THE physical, mechanical and chemical properties of the magnesium alloys distinguish these materials in many respects from other constructional metals, and since a full knowledge of the properties of these alloys is necessary for an appreciation of their advantages, and for the selection of the most suitable alloy for a particular application, a new 62-page booklet on design, issued by Magnesium Elektron, Ltd., opens with a discussion of these properties. Special attention is paid to such recent improvements as creep resistance and freedom from microporosity (resulting in pressure tightness) in the casting alloys, and to a greater ease in the working of the wrought alloys. While magnesium calls for careful application of well-known design principles rather than for new design methods, it nevertheless possesses certain characteristics which demand special consideration. These requirements are considered in the concluding sections.

"PRECISION PROCESSING" is the title of an illustrated booklet recently issued by Kodak, Ltd., in which is featured a range of X-ray processing units incorporating a number of features that help to ensure uniform, rapid and trouble-free processing. Single units and combinations of units are suggested for outputs ranging from 25–300 films an hour, and for various sizes of darkroom. Full particulars are given of each of the units concerned.

VACUUM melting is finding increasing application in modern metallurgical operations, and the June issue of *The Wild-Barfield Heat Treatment Journal* contains the first part of an article dealing with various aspects of this important process. It will be recalled that Wild-Barfield recently announced an agreement in this field with National Research Corporation of America. Other topics featured in this issue include a versatile induction hardening equipment, and practical aspects of pack carburising.

THE versatility of the platinum group of metals is strikingly brought out in the July issue of *Platinum Metals Review*, in which there are articles dealing with their use in electrical contacts, permanent magnets, catalysts, and thermocouples, and as electrodeposited coatings on anodes for the cathodic protection of ships and on slip rings in flight instruments. There is also a reference to expansion in production facilities at Rustenburg, and to "platinum four hundred years ago."

THE Directory of Members issued by the Aluminium Development Association is an 18-page publication showing the names and addresses of the member companies, together with corresponding details of their administrative and sales offices. The principal aluminium products of each company are also displayed, and these are indexed at the beginning of the publication under "aluminium" and "aluminium alloy," respectively.

Books Received

"Magnesium Casting Technology." By A. W. Brace and F. A. Allen. 174 pp. inc. classified bibliography and index. London, 1957. Chapman & Hall, Ltd. 21s. net.

"Practical Microscopical Metallography." By Dr. R. H. Greaves and H. Wrighton. Fourth Edition. 221 pp. inc. index of photomicrographs and subject index. London, 1957. Chapman & Hall, Ltd. 70s. net.

"Chromium." Vol. II. "Metallurgy of Chromium and its Alloys." By M. J. Udy. 402 pp. inc. index. New York and London, 1956. Reinhold Publishing Corporation and Chapman & Hall, Ltd. 88s. net.

LABORATORY METHODS

MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS

AUGUST, 1957. Vol. LVI, No. 334

Determination of Iron, Nickel and Lead in Blister and Refined Copper

By Silvio Barabas and W. Charles Cooper

Canadian Copper Refiners, Ltd., Montreal East, Quebec, Canada

A rapid and accurate procedure for the simultaneous estimation of iron, nickel, and lead in blister and refined copper has been developed. Copper is removed by electrodeposition, the lead deposited on the anode being redissolved. Iron and nickel are determined spectrophotometrically, and lead polarographically. Samples analysed by this procedure contained iron: 0·001–0·004%*; nickel:* 0·0007–0·15%*, and lead:* 0·0003–0·060%.

THERE is a paucity of convenient chemical procedures for the determination of impurities such as iron, nickel and lead in blister and refined copper. The available methods are lengthy and often require large samples, particularly for the small amounts of impurities encountered in refined copper.[1] Moreover, none is designed for the simultaneous estimation of several impurities. It is the purpose of this paper to report an accurate and rapid procedure, which allows the determination of iron, nickel, and lead on separate aliquots of the same mother solution on a 5 g. sample. Following this procedure, copper is first electrodeposited from a slightly acid solution, iron and nickel thereafter determined colorimetrically on small aliquots, using thiocyanate and dimethylglyoxime, respectively, while lead is estimated polarographically in hydrochloric acid medium.

Procedure

Weigh accurately a 5 g. sample and transfer to a 180 ml. electrolytic beaker. In order to remove any iron contaminating the sample, add 25 ml. of a 1 : 3 hydrochloric acid solution and boil for 10 minutes. Discard the acid and rinse carefully the undissolved sample with several portions of distilled water. Start a blank. Add a total of 30 ml. of nitric acid (5 ml. in the blank) in small portions to avoid violent reaction. Heat at a moderate temperature until all the copper has dissolved, then boil the solution until a slight green precipitate appears on the surface. Cool, rinse with distilled water and add a few drops of nitric acid if the solution is not clear. Dilute the solution to 150 ml. and add 1 drop of 0·1 N hydrochloric acid.

Now deposit the copper on a cylindrical platinum gauze cathode, adjusting the current to 1 amp. for 15 minutes, then raising it to 2·5 amp. If nitrogen oxide fumes develop, destroy them by adding a speck of urea to the solution. When the deposition of copper is complete, as shown by the absence of any deposit on a freshly exposed cathode surface, cut off the current and remove the beaker from the electrodes immediately. Rinse the anode with a few ml. of a 1 : 3 nitric acid solution. Filter into a clean 250 ml. beaker, add 5 ml. of nitric acid, and evaporate at under-boiling temperature to approximately 40 ml. Cool and make up to the mark in a 50 ml. volumetric flask (except for wire bars and electric furnace cakes—see below).

Nickel

To a 2 ml. to 10 ml. aliquot for blister copper, and to the total volume (evaporated to about 30 ml.) for refined copper, add 2 ml. of 10% citric acid solution, and oxidize nickel by adding dropwise, and with shaking, saturated bromine water until a permanent orange colour is observed. Now add dropwise ammonium hydroxide until the solution turns colourless again, and then 10 drops in excess. If the deposition of copper has not been complete, as noted by the blue colour of the cuprammonium ion, take a new aliquot, dilute to 30 ml., warm, and treat with 20 ml. of a saturated hydrogen sulphide solution. Simmer for a few minutes, then filter. Boil the filtrate for 10 minutes to expel hydrogen sulphide. Transfer the solution, with a volume not more than 30 ml., to a 50 ml. volumetric flask and treat for nickel as indicated above. Cool the solution to room temperature and add 1 ml. of a 1% ethanol solution of dimethylgloxime. Make up to the mark and determine the absorbance within 15 minutes at 450 mμ. *vs.* the blank. Read from the calibration curve the milligrams of nickel in the aliquot.

Iron

Pipette a 15 ml. aliquot into a 50 ml. volumetric flask, add by burette 30 ml. of acetone and 5 ml. of ammonium thiocyanate solution (250 g./l), and mix well. Measure the absorbance of the solution within half an hour at 470 mμ. *vs.* the blank. Read from the calibration curve the milligrams of iron in the aliquot.

Lead in Blister Copper

Transfer a 10 ml. to 25 ml. aliquot to a 100 ml. beaker. Evaporate to dryness. Rinse the beaker with distilled water and take again to dryness. Remove the beaker from the hot plate, add 2 ml. of nitric acid, mix to dissolve the residue, and add 5 ml. of ammonium hydroxide and 5 ml. of 10% ammonium carbonate solution. Bring to boiling, simmer for 10 minutes to

* Presented before the Division of Analytical Chemistry, 38th Annual Conference, The Chemical Institute of Canada, Quebec City, 1955.

TABLE I.—SPECTROPHOTOMETRIC DETERMINATION OF IRON IN COPPER WITH THIOCYANATE

Iron Present (μg.)	Iron Found (μg.)
30	29
60	60
90	90
120	122

coagulate the lead and iron precipitate and filter. Wash a few times with 1% ammonia solution. Now dissolve the precipitate in a few ml. of hot 1 : 1 nitric acid, rinse with a few ml. of hot water and bring to dryness. Rinse the beaker with distilled water and bring again to dryness.

Take the beaker from the hot plate, cool somewhat and dissolve the residue in 4 ml. of 2 N hydrochloric acid. Transfer a portion of this solution to a micro-polarographic cell, de-aerate the solution and record the polarogram between $-0{\cdot}25$ and $-0{\cdot}65$ volt *vs.* mercury pool. Measure carefully the height of the polarographic wave by the tangential method, and determine the lead in the sample by reference to a wave height-concentration plot.

Lead in Refined Copper

Carry through this analysis on the 35 ml. of solution remaining from the iron determination. This time dissolve the residue in 2 ml. of 2 N hydrochloric acid. Record the polarogram and measure the wave height. Determine the amount of lead in the sample from the working curve.

Discussion

In the electrolytic determination of copper in refined copper, the main interfering elements are: silver, selenium, tellurium, arsenic, antimony and bismuth, all of which deposit partially or completely on the cathode. The cathodic deposition of selenium, tellurium, arsenic and antimony may be prevented by adding to the electrolyte strong oxidizing substances like potassium persulphate and permanganate. In the present procedure no oxidants are added. The co-deposition of impurities is regarded as an advantage, since some of these impurities might interfere, if present after electrolysis, in the subsequent determinations.

The electrolysis is carried out in a slightly acid nitric solution to which one drop of 0·1 N hydrochloric acid is added for its catalytic depolarizing action. Nitrogen oxide fumes, if developed during electrolysis, are promptly destroyed by adding a speck of urea. The objection to the use of urea in the electrolytic determination of copper, *viz.* the probable formation of carbon residue which would contaminate the copper deposit, has no basis here. Sulphamic acid or hydrazine sulphate, if added, would cause the formation of sulphuric acid, which is undesirable.

Iron

Following the removal of copper and the acid dissolution of the anodic lead deposit, iron is determined on a suitable aliquot containing 0·01–0·1 mg. of iron. The

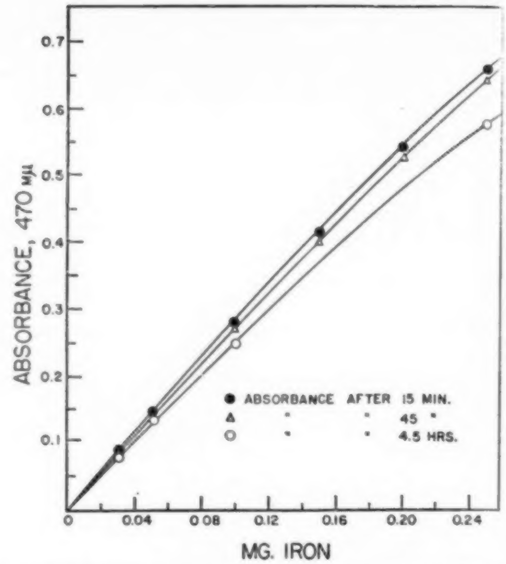


Fig. 1.—Spectrophotometric determination of iron with thiocyanate solutions 0.8 N in nitric acid, 25% by volume in acetone, and 0.33 M in ammonium thiocyanate.

ferric thiocyanate colour intensity was checked against time, acidity, acetone and thiocyanate concentration. According to Sandell,[2] the ferric thiocyanate colour intensity in a 0·5 N nitric acid solution decreases in the first 15 minutes, then increases, eventually becoming stronger than it was originally. According to our experience, a wide range of iron concentrations in 0·8 N nitric acid solution and 25% acetone shows for all practical purposes an insignificant decrease in colour intensity in the first 45 minutes. However, the intensity drops approximately 12% in the next 4 hours (Fig. 1).

While acidity had no influence on the colour intensity in the range 0·16–1·6 N nitric acid, it was observed that the acetone and thiocyanate additions must be measured very accurately. An increase from 10% to 60% in acetone causes a 55% increase in absorbance, while an increase from 0·066–0·49 M ammonium thiocyanate brings about a 60% increase in absorbance of the ferric thiocyanate complex. All iron determinations were made on solutions which were 0·32 N in nitric acid, 0·33 M in ammonium thiocyanate and 60% in acetone.

To check the recovery of iron by this procedure, known amounts of iron were added to 2·5 g. portions of wire bar copper, previously boiled for 5 minutes with diluted (1 : 3) hydrochloric acid to remove any external iron contamination. Table I shows the added and recovered amounts of iron.

If copper were not completely deposited during the electrolysis, it would combine with thiocyanate and the iron results would be too high. On the other hand, if iron is precipitated as hydroxide after the electrolysis and then redissolved and determined spectrophoto-

TABLE II.—SPECTROPHOTOMETRIC DETERMINATION OF IRON IN COPPER WITH THIOCYANATE. (IRON SEPARATED AS HYDROXIDE FROM THE ELECTROLYTE SOLUTION)

Iron Present (μg.)	Iron Found (μg.)
45	45
100	96
150	142
200	188

TABLE III.—SPECTROPHOTOMETRIC DETERMINATION OF NICKEL IN COPPER WITH DIMETHYLGLYOXIME

Nickel Present (μg.)	Nickel Found (μg.)
40	40
80	80
120	119
160	158

TABLE IV.—POLAROGRAPHIC DETERMINATION OF LEAD IN COPPER

Lead Present (μg.)	Lead Found (μg.)
30	30
60	60
90	86
150	146

TABLE V.—IRON, NICKEL AND LEAD IN COPPER

Material	Iron (%)	Nickel (%)	Lead (%)
Wire Bar Copper	0·0020	0·0009	0·0005
Electric Furnace Copper Cake	0·0020	0·0015	0·0008
Blister Copper	0·0021	0·041	0·021
Anode Copper A	0·0022	0·107	0·0022
Anode Copper B	0·0018	0·029	0·042

metrically, the results are somewhat low. Table II shows the added and found amounts of iron after iron has been separated from the electrolyte solution.

Nickel

Nickel is determined on another aliquot containing from 0·05–0·2 mg. of nickel by the colorimetric dimethylgloxime procedure. Citric acid was added to prevent the precipitation of iron, and a few drops of bromine served to oxidize nickel to the quadrivalent state. The recovery of nickel by this procedure was checked by adding known amounts of nickel to 2·5 g. portions of copper wire bar. Table III shows added and recovered amounts of nickel.

Lead

Lead is precipitated from another portion of the mother solution as basic lead carbonate by adding to the ammonical solution saturated ammonium carbonate. The lead separation is not complete in the absence of iron. However, the amount of iron usually found in copper assures complete precipitation of lead. Since the lead is to be determined polarographically, and as the polarographic iron wave immediately precedes that of lead, it is important that the iron content be not too high.

Following the dissolution of the precipitate in nitric acid and evaporation to dryness, the residue is taken up in a specified volume of 2 N hydrochloric acid and the resulting solution polarographed directly with no maximum suppressor added. This supporting electrolyte is superior to the ammonium chloride-nitric acid medium of Hohn[3], in which a distortion of the wave, presumably due to the reduction of nitrate, was observed. This distortion was found to be completely suppressed in the presence of 0·03% of carboxymethylcellulose.

Table IV shows the recovery of lead added to copper wire bar following the prescribed procedure.

Analyses of iron, lead and nickel in various copper materials are shown in Table V.

REFERENCES

1 Furman, N. H. (editor), " Scott's Standard Methods of Chemical Analysis," 5th ed., Vol. I, pp. 381–386, D. Van Nostrand Company, Inc., New York, 1939.

2 Sandell, E. B., " Colorimetric Determination of Traces of Metals," 2nd ed., p. 367, Interscience Publishers Inc., New York, 1950.

3 Hohn, H., *Z. Elektrochem.*, **43**, 127 (1937).

Society of Instrument Technology Data-Processing Section

THE Society of Instrument Technology is setting up a special section to cater for the current interest in data-processing systems. This section will begin to hold meetings in London this autumn and four papers are scheduled for the first session :—

Thursday, October 10th—" A System for Handling Wind-Tunnel Data," by J. F. M. SCHOLES, of R.A.E., Bedford.

Thursday, November 14th—" A Digital Plotting Table," by J. MORRISON, of Dobbie, McInnes, Ltd.

Tuesday, January 28th—" Digital Codes and Coding," by M. P. ATKINSON, of N.P.L.

Tuesday, April 29th—a joint meeting on " Scanning and Logging," with papers by D. H. WHITING and J. DUNKLEY, of I.C.I., and J. CHURCHILL, of Sunvic Controls, Ltd.

The Society, because of its association with designers and users of instruments, can provide the necessary centre for discussion of some of the most important aspects of data-processing. Initial emphasis will be on systems for handling experimental data, and for industrial monitoring and control. The section will be concerned with system design as well as with the detailed design of equipment ; it will also deal with the use and organisation of systems and with design-study work. The literature on data-processing techniques and application is scattered, and much existing knowledge remains unpublished ; one of the section's first tasks will be to obtain papers that review the present stage of development.

Further information may be obtained from the Secretary, S.I.T., 20, Queen Anne Street, London, W.1. Anyone interested in contributing to the activities of the section should write to the Section Secretary, W. T. Banc, 137, Kenilworth Court, London, S.W.15.

Cambridge in Holland

DURING Cambridge Week in the old Dutch University City of Leiden, which was held from June 24th to 29th, to present the City of Cambridge in all its commercial, municipal and university aspects to the people of Leiden, the Cambridge Instrument Company, one of the two largest engineering organisations in the City of Cambridge exhibited a comprehensive selection of instruments designed for measurement (indicating and recording) and control in science and industry. Individual measurements covered temperature, gas analysis (including the detection of CO and CO_2 in flue gases), *p*H, conductivity, humidity, polarography, metrology, electrical (A.C. and D.C.), radiation intensity, rubber hardness, cardiology, physiological investigations, etc.

Fielden Electronics, Ltd.

A MAJOR holding in Fielden Electronics, Ltd., has been purchased by Hopkinsons, Ltd., of Huddersfield, the well-known manufacturers of boiler fittings and controls. This new association will provide the necessary finances for the continued expansion of the Company. Mr. J. E. Fielden the founder, still retains a substantial shareholding, and will continue to guide its future as Chairman and Managing Director.

Change of Address

THE headquarters of the Raw Materials Division of George Cohen, Sons & Co., Ltd., have been moved from Broadway Chambers, Hammersmith, to 600, Wood Lane, Shepherds Bush, London, W.12.

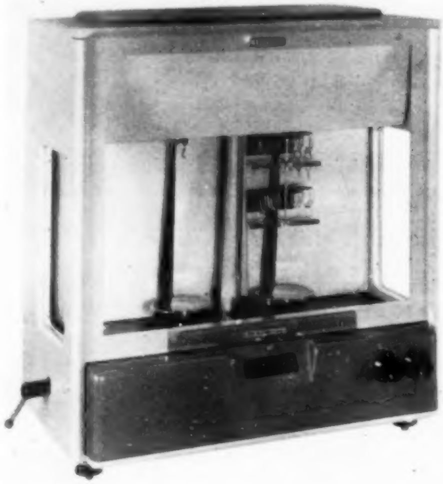
Items of Metallurgical Interest at Recent Instrument Exhibitions

The recent Instruments, Electronics and Automation Exhibition at Olympia aroused considerable interest, as might be expected at a time when automatic devices are finding increasing application in industry and commerce. In this and subsequent issues, reference will be made to items of metallurgical interest exhibited at Olympia, and at the Physical Society Exhibition which, as usual, provided an opportunity for the display of new commercially available and prototype instruments and laboratory equipment.

Micro-Hardness Tester

THE usual micro-hardness test is similar in principle to the Vickers hardness test, in that a diamond indenter is pressed into the surface to be tested with a known force and the size of the resulting impression used as a measure of the hardness. In the G.K.N. micro-hardness tester shown at Olympia by the Instrument Division of Associated Automation, Ltd., a 136° angle diamond pyramid indenter is used and the applied load can be varied from 1 to 100 g. Because of the low loads compared with the Vickers hardness tester, the impressions are very much smaller, and in this way the hardness of very small areas of a specimen may be determined.

The G.K.N. instrument is suitable for fitting to a bench type metallurgical microscope having a screw micrometer eyepiece, and is suitable for performing either indentation or scratch tests. Although it can in some instances be used for process control, it is primarily an additional tool for metallurgical or mineralogical research. It is particularly valuable for determining the hardness of individual phases in metallurgical microstructures, and for hardness testing very thin material, such as shim-stock, hardened surface layers, and electroplated deposits. Other applications include the testing of fine wires, watch and clock parts, and instrument pivots and bearings.



Oertling Model FO.5 balance.

G.K.N. micro-hardness tester.

Analytical Balances

Although the chemical balance has been in use for more than a hundred years, it has maintained its superficial appearance until recently, in spite of such important advances as the use of corundum planes and the introduction of an automatic mechanism for protecting the knife-edges from damage during the release of the beam. These developments were pioneered by Oertling, who have been making balances since 1847, and who showed their full range of balances at the Instrument, Electronics and Automation Exhibition, including the new models of single- and two-pan balances of advanced design and construction.

As a result of time and motion study, careful attention has been given to the position of controls, their ease of manipulation, and the display of the weight reading. Modern materials have been used in the construction of these new models, an interesting example being the aluminium-magnesium alloy, with high resistance to corrosion and freedom from creep, from which the beams are made. The use of light alloy casting and

Foxboro-Yoxall magnetic flow meter.

fabrication techniques has enabled a chassis form of construction to be employed which gives greater mechanical stability and a much higher degree of accuracy than was formerly possible.

The balance case no longer forms part of the instrument proper, carrying, among other things, the weight loading mechanism and part of the optical projection system, but performs its real function of protecting the balance from dust, draught and heat. This new type of construction allows the balance to be totally enclosed, leaving only the pans exposed. The improvement in stability has enabled the Company to publish the accuracy of its instruments in terms of the standard deviation. It is believed that this is the first occasion on which a balance manufacturer has felt able to indicate to the user the order of accuracy or precision which may be expected.

Magnetic Flow Meter

THE magnetic flow meter shown by Foxboro-Yoxall has been developed to meet the need for a fluid flow meter which will measure the volume rate of all fluids with an electrical conductivity. There is no restriction of the flow line, no loss of head and no pressure taps to become blocked, so that fluids of the types mentioned are measured with sustained accuracy. It is simple to instal and its performance is unaffected by surrounding pipework arrangements, variations in density, turbulence, viscosity or suspended materials.

The magnetic flow meter comprises the transmitter and a Dynalog flow receiver which may be an indicator, a recorder or a multi-record Dynalog. The flow scale is uniformly linear and the meter has a rangeability of 100 to 1. The transmitter itself consists of a stainless steel tube through which the liquid passes, an electrical insulating liner on the inside of the tube, an electromagnet which induces a magnetic field across the tube and two metallic electrodes which are essentially flush with the inside surface of the tube. Transmitters are now made in line sizes varying from 2 in. to 8 in. (other sizes by request), suitable for flow rates from 0-2,500 g.p.m. to 0–40,000 g.p.m. The measurement of reversing flows is easily obtained, and a totalizer may be included, either locally or remotely, to give flow totals in any desired units.

Polarographs

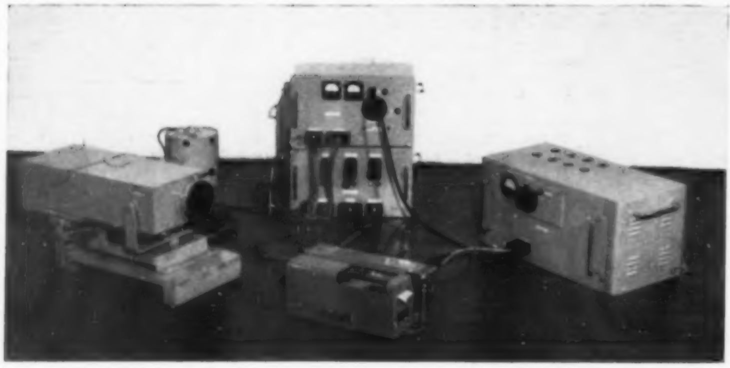
Polarography is a rapid and accurate technique of chemical analysis in which the electrolysis of solutions between a dropping mercury cathode and a mercury pool anode is studied. During the electrolysis, a voltage which increases at a uniform rate is applied to the cell and the current/voltage curves are recorded. From a study of these curves, which are known as polarograms, the character and concentration of the substances in solution can be determined.

The Tinsley Mark 17 polarograph shown by Evershed and Vignoles, Ltd., at Olympia, has been designed for laboratories and other establishments where the scope of the work is such that only the most rapid and accurate technique of chemical analysis will suffice. It is a recording instrument with a range of sensitivities from $0 \cdot 1\mu$A. to 150μA. in 34 steps. A derivative circuit is incorporated, and there are two time constants for polarograms: (*a*) where sensitivity of trace analysis is essential; and (*b*) where high resolution is of prime importance.

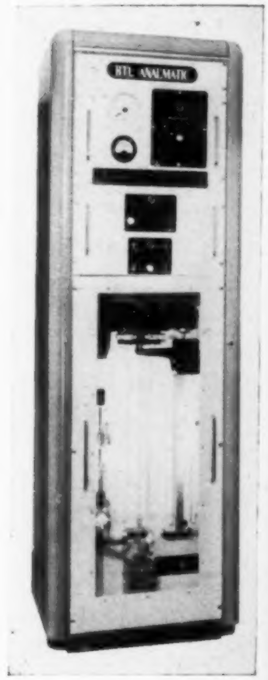
Four stages of electrical damping are available, and the damping switch is so arranged that very fine control may be obtained for different dropping rates of the capillary with extra optional damping in the maximum damped position. The vibration proof D.C. amplifier gives distortionless and linear amplification, and the whole instrument has been designed to allow access to the components for servicing.

The Mark 16 polarograph has been introduced to meet the need for a smaller and less expensive instrument suitable for instructional purposes, and for laboratories where the volume and scope of the work may not warrant the outlay for the larger type of recording unit. It is the only non-recording polarograph with a derivative circuit, and its range of sensitivities varies from 100μA. full-scale deflection to $0 \cdot 02\mu$A. in 16 steps. In order to make use of the high sensitivity, a special capillary can now be obtained from Eversheds, which is bent through a right angle so that the orifice, through which the drops emerge, lies in a horizontal plane with the actual surface vertical. The mercury drops are thus sheared off in a controlled manner, and with this method resolution at high sensitivities is much greater than that obtainable using the classical straight dropping mercury electrode.

Tinsley Polarograph—Mark 17.



G.E.C. photoelectric telepyrometer (left) with high-speed pen recorder (foreground) and associated power supply units.



Baird and Tatlock Analmatic auto-titrator.

Photoelectric High-Speed Recording Telepyrometer

This instrument, shown by The General Electric Co., Ltd., measures the instantaneous temperature of molten glass, and will record the temperature in 0·5 sec. with an accuracy to $\pm 1°$ C. within the range 900–1,200° C. The pyrometer is designed to operate about 12 ft. away from the surface of the glass to be measured, and a telescope with 3 in. diameter objective is used to collect sufficient radiation from chosen small areas of glass down to about 1 in. diameter. In the image plane of the telescope, a small aperture in front of a photocell restricts the field of view to the required angular subtense of about 0·4°. The light so received is compared with that from a calibrated tungsten filament comparison lamp, adjusted in intensity so that the signal which it produces from the photocell is the same as that produced by a full radiator at a known temperature. This comparison is achieved by means of a rotating sector mirror which alternatively presents the two radiations to the photocell. Provision is made for adjusting the comparison source to one of several temperature-measuring scales, which can be set appropriately to within 20° C. of the temperature of the test source. Any remaining difference from the comparison source will give rise of an A.C. signal from the photocell. After suitable amplification and rectification, this signal operates a high speed pen recorder which indicates the instantaneous temperatures.

Auto-Titrator

The Baird and Tatlock Analmatic Auto-Titrator is used for measurements requiring a titration where a potentiometric or *p*H end-point is applicable. The potential produced by two electrodes immersed in the solution being titrated is amplified and compared with two preset values. Titrant is added continuously until this potential reaches the first value (arranged to be slightly before the end-point), and then dropwise to the end-point. Only one valve is used to control the addition, and the drop-frequency may be adjusted over a wide range. False end-points before the true one are avoided by a delay system in the control unit. When the true end-point is reached the burette is read automatically by a photo-electric meniscus follower system, and the result is printed on a paper strip. This result may be in any convenient system of units, the necessary calculation from volume to the final answer being allowed for in the instrument.

In the equipment shown, the sample liquor is measured into the titration vessel automatically, an additional reagent is added, and the mixed solution diluted to a convenient volume for the titration. After the titration has been completed, and the result recorded, the sample pipette is rinsed with a fresh sample, the titration vessel is washed out, and the burette refilled to zero ready for the next cycle. The whole cycle of events is carried out automatically, and may be individually designed to deal with specific applications.

Safety and Health in Welding

THE Institute of Welding is organising a special one-day course on safety and health aspects of welding. Planned for the benefit of industrial nurses and safety officers, it will be held on October 12th, 1957. It aims to explain how the welding processes give rise to certain hazards, and to describe their clinical effects: the law in regard to the use of welding, and the steps necessary to ensure the health and safety of workers, will be discussed. Guidance on the investigation of welding hazards will also be given.

An enrolment fee of £2 12s. 6d. will be charged for the course, which will include the cost of all meals and refreshments. As only a limited number of enrolments can be accepted, early application should be made to the Secretary, the Institute of Welding, 54, Princes Gate, London, S.W.7.

Change of Address

THE address of the London Office of Wm. Beardmore & Co., Ltd., has been changed to 11, Hamilton Place, Piccadilly (Hyde Park Corner), London, W.1. (Tel.: Grosvenor 8786).

red
nal
o a
ion
ple
ssel
for
out
eal

day
ned
ers,
ain
ds,
ard
ure
ed.
will

he
nd
nts
he
te,

&
e,
. :